NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

MBA PROFESSIONAL REPORT

ANALYSIS OF NAVAL AMMUNITION STOCK POSITIONING

December 2015

By: **David Sharp**
Eric Rossmanith

Advisors: **Geraldo Ferrer**
Kenneth Doerr

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REPORT DOCUMENTATION PAGE	*Form Approved OMB No. 0704–0188*

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instruction, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188) Washington, DC 20503.

1. AGENCY USE ONLY *(Leave blank)*	**2. REPORT DATE** December 2015	**3. REPORT TYPE AND DATES COVERED** MBA professional report

4. TITLE AND SUBTITLE ANALYSIS OF NAVAL AMMUNITION STOCK POSITIONING	**5. FUNDING NUMBERS**
6. AUTHOR(S) David Sharp and Eric Rossmanith	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Postgraduate School Monterey, CA 93943-5000	**8. PERFORMING ORGANIZATION REPORT NUMBER**
9. SPONSORING /MONITORING AGENCY NAME(S) AND ADDRESS(ES) N/A	**10. SPONSORING / MONITORING AGENCY REPORT NUMBER**

11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government. IRB Protocol number ____N/A____.

12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution is unlimited	**12b. DISTRIBUTION CODE**

13. ABSTRACT (maximum 200 words)

Naval Supply Systems Command Global Logistics Support Ammunition (NAVSUP GLS AMMO) is considering an alteration of the current Navy ammunition stock positioning system. The purpose of this project is to analyze the cost and delivery performance risk associated with either centralizing the Navy's ammunition stockpiles and positioning them at an inland Army depot or decentralizing the ammunition stockpiles and positioning them at coastal Navy facilities. A Monte-Carlo simulation model was developed to simulate expected cost and delivery performance risk using historical demand data and rates provided by NAVSUP GLS AMMO. These measures of risk enable NAVSUP GLS AMMO to determine the probability that the centralized or decentralized system will outperform the status quo system with regard to cost and delivery performance.

14. SUBJECT TERMS supply chain management, Monte-Carlo simulation, risk, delivery performance, stock positioning	**15. NUMBER OF PAGES** 85
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	**18. SECURITY CLASSIFICATION OF THIS PAGE**	**19. SECURITY CLASSIFICATION OF ABSTRACT**	**20. LIMITATION OF ABSTRACT**
Unclassified	Unclassified	Unclassified	UU

NSN 7540–01-280-5500

Standard Form 298 (Rev. 2–89)
Prescribed by ANSI Std. 239–18

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ANALYSIS OF NAVAL AMMUNITION STOCK POSITIONING

David Sharp, Captain, United States Marine Corps
Eric Rossmanith, Captain, United States Marine Corps

Submitted in partial fulfillment of the requirements for the degree of

MASTER OF BUSINESS ADMINISTRATION

from the

NAVAL POSTGRADUATE SCHOOL
December 2015

Approved by: Geraldo Ferrer

Kenneth Doerr

Bryan Hudgens
Academic Associate
Graduate School of Business and Public Policy

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ABSTRACT

Naval Supply Systems Command Global Logistics Support Ammunition (NAVSUP GLS AMMO) is considering an alteration of the current Navy ammunition stock positioning system. The purpose of this project is to analyze the cost and delivery performance risk associated with either centralizing the Navy's ammunition stockpiles and positioning them at an inland Army depot or decentralizing the ammunition stockpiles and positioning them at coastal Navy facilities. A Monte-Carlo simulation model was developed to simulate expected cost and delivery performance risk using historical demand data and rates provided by NAVSUP GLS AMMO. These measures of risk enable NAVSUP GLS AMMO to determine the probability that the centralized or decentralized system will outperform the status quo system with regard to cost and delivery performance.

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LIST OF ACRONYMS AND ABBREVIATIONS

AMMO	Ammunition
AVG	Average
CAD	Cartridge Actuated Device
COG	Cognizance
CONUS	Continental United States
DLATS	Defense Logistics Agency Transaction Service
DOD	Department of Defense
DODD	Department of Defense Directive
DODI	Department of Defense Instruction
GLS	Global Logistics Support
JMC	Joint Munitions Command
JSAABR	Joint Shipboard Ammunition and Ammunition Boards
LMS	Logistics Management Specialist
MAX	Maximum
MIN	Minimum
MRO	Material Release Order
NAVAIR	Naval Air Systems Command
NAVSEA	Naval Sea Systems Command
NAVSUP	Naval Supply Systems Command
NMC	Naval Munitions Command
NW	Northwest
OIS	Ordnance Information System
OIS-R	Ordnance Information System-Retail
OIS-W	Ordnance Information System-Worldwide
PAD	Propellant Actuated Device
ROLMS	Retail Ordnance Logistics Management System
RDD	Required Delivery Date
S2S	Site-to-site

SE	Southeast
SOS	Source of Supply
SMCA	Single Manager for Conventional Ammunition
SUBROC	Submarine Rocket
USSOCOM	United States Special Operations Command

I. INTRODUCTION

A. OVERVIEW

The management of Navy ammunition is unique in comparison to other repairable and consumable materials because of its hazardous and/or explosive nature. Ammunition stockpile management requires a high degree of control. There are organizations within the Department of Defense (DOD) to take on the responsibilities of procurement, stockpile management, storage, handling, and distribution to the end users. Although the Secretary of the Army is appointed as the Single Manager for Conventional Ammunition (SMCA), the Navy has its own organization for the unique business practices involving naval ammunition (Department of Defense [DOD], 2008).

This chapter will provide the reader with an overview of both the business processes of Navy retail ammunition management (as outlined by NAVSUP P-724, the publication for conventional ordnance stockpile management) and will describe the background, purpose, and research questions that are being addressed in this project.

B. NAVAL SUPPLY SYSTEMS COMMAND AMMO BUSINESS PROCESSES

NAVSUP refers to the management of ammunition inventory as "Ammunition Stockpile Management" and established the Naval Supply Systems Command Global Logistics Support Ammunition (NAVSUP GLS AMMO) as both the wholesale and retail stockpile manager for Navy-unique, in-service ammunition items (Naval Supply Systems [NAVSUP], 2015). Their responsibilities include acting as the ammunition support agent, coordinating fleet requirements, resolving issues, and controlling the distribution of ordnance (NAVSUP, 2015). Ammunition product lines are categorized under a cognizance (COG) code, along with other similar munitions. Table 1 displays the different COGs, the ammunition family that describes that COG, and the ammunition category or type that is a member of the ammunition family.

Table 1. Ammunition Cognizance Symbol.

COG	Ammunition Family	Ammunition Category/Type
0T	Marine Corps Ammunition	Marine Corps Ground Ammunition
2D	Tomahawk Missile/Components	Tomahawk Cruise Missiles
2E	Air Ammunition	Bombs
		Military Pyrotechnics
		Underwater Sound Signals and Sonobuoys
		Cartridge Actuated Devices/Propellant Actuated Devices (CAD/PAD)
		Aircraft Rockets
		Miscellaneous Ammunition and Containers
		Gun Ammunition, 20MM to 4 Inch
		Decoys and Countermeasures
		Bulk Explosives and Solid Propellants
2T	Surface/Underwater Ammunition	Military Pyrotechnics
		Military Chemicals
		Demolition Explosives and Material
		Miscellaneous Ammunition and Containers
		Small Arms and Landing Force Ammunition
		Gun Ammunition, 20MM to 4 Inch
		Gun Ammunition, Over 4 Inch
		Decoys and Countermeasures
		Cartridge Actuated Devices/Propellant Actuated Devices (CAD/PAD)
		Bulk Explosives and Solid Propellants
		Smokeless Powder
4T	Torpedoes and Components	Torpedoes and Components
6T	Mines	Underwater Mines
6Z	JSAABR Material	USSOCOM Specialized Equipment
8E	Air/Surface Launched Missiles (NAVAIR)	Air Launched Guided Missiles
8S	SUBROC Material/Mobile Submarine Simulator	SUBROC Material/Mobile Submarine Simulator
8T	Surface Launched Missiles (NAVSEA)	Surface Launched Guided Missiles
8U	Sonobuoys	Sonobuoys

Source: Navy Supply Systems Command. (2015). *Conventional ordnance stockpile management policies and procedures* (NAVSUP P-724) (pp. 1–2). (21 ed.). Mechanicsburg, PA: Author.

Traditional inventory management consists of building stock levels that are demand based, often using an economic order quantity, reorder point, and a safety stock as protection from demand and lead time variability. Because of the uniqueness of ammunition management, NAVSUP's approach to building stock levels is program based; using programmed requirements called "load plans" (NAVSUP, 2015, pp. 1-3).

Fundamentally, the load plan is a stock level that supports fleet requirements for both noncombat expenditure allocation and an activity's operational allowance. Once the fleet requirements are identified and approved by Fleet Commands and Marine Forces Commands, ammunition stock points provide projected commitments for storage space requirements for the load plan. The stock positioning of ammunition to support the fleet requirements is also part of the load plan; thus creating a system where each activity is mapped to a single stock point in their geographic region. One stock point has many activities mapped to it, and one activity is mapped to one stock point. Under the Global Requirements Based Load Plan, the aggregate of all supported activities' allowances mapped to a given stock point become that stock point's load plan and stock level (NAVSUP, 2015).

DOD Directive (DODD) 5160.65 assigned the Secretary of the Army as the SMCA (DOD, 2008). Retail stock points for Navy-retained munitions excluded from management by the SMCA, as outlined in DODD 5160.65, are stored in Navy facilities located on both the East and West Coasts. Munitions that are Navy assets, but are not excluded as outlined in DODD 5160.65, are stocked at inland Army depots managed by the Army Joint Munitions Command (JMC). Assets that are not excluded, however, may also be stocked at a Naval Munitions Command (NMC).

Activities submit requisitions, or demand signals, for ammunition for either training or as a part of their operational allowance. The material release order (MRO) is typically sent to that activity's mapped stock point, or assigned NMC, as a signal to issue the ammunition, but can also be released to another NMC in the event that the customer is afloat and is closer to an NMC that they are not assigned to. In a situation where there is a shortage at the nearest NMC, a transshipment, or site-to-site transfer, from a different NMC is executed to satisfy the requirement (NAVSUP, 2015). The ability of an NMC to satisfy a customer's demand at the first level is measured as "first-pass effectiveness."

Requisitions for ammunition are submitted by activities via the OIS-Retail/Retail Ordnance Logistics Management System (OIS-R/ROLMS) and received by a Logistics Management Specialist (LMS) using OIS-Worldwide (OIS-W) via an interface called the Defense Logistics Agency Transaction Service (DLATS). The activity indicates their required delivery date (RDD) in the requisition to notify the stock point of the date by which the ammunition is required to be delivered. Once the requisition is received by the LMS in OIS-W via the DLATS, it is verified and can either be returned, cancelled, modified, or released. If it is a valid requisition, it is released as an MRO to the appropriate stock point for issue. Once the MRO is received by the issuing stock point, the ammunition is pulled from inventory and prepared for shipment in time to meet the activity's RDD. Oftentimes, the activity will requisition ammunition well in advance, providing the supply chain with adequate time to respond.

C. BACKGROUND, SCOPE, AND PURPOSE

The Under Secretary of Defense (Acquisition, Technology, and Logistics), set guidance for the management of material across the DOD through the release of DOD Instruction (DODI) 4140.01. The policy, as established by DODI 4140.01 with regard to the supply chain, is that "DOD [*sic*] materiel management shall operate as a high-performing and agile supply chain responsive to customer requirements during peacetime and war while balancing risk and total cost" (DOD, 2011, p. 2).

1. Background

NAVSUP GLS AMMO is searching for opportunities to reduce the cost of the ammunition supply chain while not impairing its ability to provide reliable delivery of ordnance to its customers. They are interested in researching how stock positioning would have an impact on the cost and delivery performance of the supply chain.

Stock positioning for the ammunition product lines vary. While some stock points are positioned close to customer demand at coastal facilities, others are positioned at inland Army depots that fall under the Army JMC. NAVSUP GLS AMMO is considering either a centralized or a decentralized stock positioning system. A centralized system is characterized by the consolidation of all product lines into the centralized inland Army depots. A decentralized system is characterized by the removal of all product lines from the inland Army depots and positioning them at the various decentralized coastal Navy facilities. The performance attributes under consideration for either system are cost and delivery performance.

2. Purpose of the Project

The purpose of this project is to perform an analysis on the effect that stock positioning has on cost and delivery performance by determining the level of risk associated with switching from the status-quo system to either the centralized or decentralized system.

This project addresses the following research questions:

- How is delivery performance sensitive to the position of a stock point?
- How is cost sensitive to the position of a stock point?
- How do site-to-site transfers affect cost and delivery performance?

The project can provide a framework for NAVSUP GLS AMMO to identify how stock positioning might affect the cost and delivery performance of its supply chain, and select the system that has the highest probability of satisfying the customer’s RDD, while minimizing the total cost. The analysis is supported by literature that describes the business practices in use by other organizations to determine stock positions, exploits the potential savings, and measures the delivery performance of the supply chain.

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II. LITERATURE REVIEW

A. OVERVIEW

This project considers how stock positioning impacts the cost and delivery performance of the ammunition supply chain. Much of the open literature presents theory and working models to assist in the decision of where to position stock for optimal cost performance, but there is no single piece that incorporates expected delivery performance with that decision. The purpose of this chapter is to review literature that presents a framework for stock positioning decisions and delivery performance.

B. STOCK POSITIONING

Stock positioning decisions may be based on several attributes and involve an analysis of the trade-offs between the costs of transportation, inventory, and materiel handling. The decision to position stock close to customer demand may be made if the desired effect is to shorten customer wait time. This can result in multiple, decentralized locations holding like items and serving their own customers. While customer wait time may be lower, the cost of holding inventory is often higher than it would be if the stock was pooled and positioned centrally. Centralizing the stock can result in savings from a decrease in facilities, handling, and personnel, but result in an increase in shipping costs. NAVSUP GLS AMMO faces a stock positioning decision with the objective to minimize cost.

Many articles present frameworks for modeling optimal supply system performance. Sherbrooke (1968) introduced a model he calls “METRIC.” METRIC is a mathematical model for use in a multiechelon supply chain that aids in the optimization, redistribution, and evaluation of the inventory control of a weapon-system line item demanded at multiple decentralized bases supported by a central depot (Sherbrooke, 1968). While his model is able to provide a solution for the allocation of the stock between bases, the goal of this model is not to find an optimal solution, but to simulate the resulting cost and delivery performance effect from reallocating stock.

Peltz, Girandini, Robbins, and Boren (2008) analyzed global inventory management and stock positioning during Operation Iraqi Freedom. This was an effort to make a recommendation to the Army and the Defense Logistics Agency on how to best design their distribution system in a way that meets customer response needs at the lowest cost. They recommended positioning items with high recurring demand and low price-to-weight ratios closest to the end user to produce the greatest return on investment (Peltz, Girandini, Robbins, Boren, 2008). The opportunities that existed included a transportation cost reduction from the reduced use of strategic airlift for sustainment, and an improvement in customer wait time. NAVSUP GLS AMMO faces a similar decision of positioning the stock near or far from the customer; however, this project does not consider the lead time associated with replenishing stock because it is expected to be the same regardless of where it is positioned.

Shahabi, Akbarinasaji, Unnikrishnan, and James developed a mathematical model to coordinate facility and inventory control for a multiechelon supply chain. They use commercial solvers for the network design problem to minimize the facility location, transportation, and inventory cost (Shahabi, Akbarinasaji, Unnikrishnan, 2013). Similarly, this project consists of developing a model of facility location and inventory costs. The authors, however, did not consider delivery performance as a contributing factor to facility location, as it is a feature included in this project's model.

Askin, Baffo, and Xia (2014) considered the problem of selecting a warehouse location in a multiechelon scenario, with facility, inventory, and transportation costs associated with the decision. The result of the study is a model that assists in determining the location and capacity of the storage facilities, the distribution routes, and the quantities of materials to stock at each echelon (Askin, Baffo, Xia, 2014). This project considers the transportation costs associated with the facility location as well as the cost to implement, or to relocate, the ammunition to the new facility. This project does not consider the different routes of transportation, or the capacity of the mode of transportation.

A decentralized system may include multiple stock points holding like items and serving their own customers. Because they may be holding like items, opportunities exist to share these items across sites and to conduct transshipments, rather than maintain a backorder. Oswald, Atkinson, and Ferrer (2015) indicated that inventory balancing among three Naval Air Station supply depots, through the effective use of lateral transshipments, can reduce the total costs system-wide when there are optimal business rules in place for control. The results of the analysis demonstrated that effective balancing through the continuous updating of an item's reorder point and the redistribution of items that are in excess in some locations, while deficient in others, can produce cost savings that are not offset by the transshipment costs (Oswald, Atkinson, Ferrer., 2015). NAVSUP GLS AMMO currently utilizes transshipments, called site-to-site transfers, to satisfy shortages from an activity's assigned NMC. This project does consider the costs associated with transshipments, but does not consider inventory balancing prior to demand.

C. DELIVERY PERFORMANCE

The ability of the ammunition supply chain to deliver on time, as required by the customer, is critical. Operational units go to great extents to synchronize resource planning with deployment timelines. In many cases, there may be a short window of opportunity for an activity to receive and upload materials dockside. In general, customers place a high value on delivery timeliness and reliability from their suppliers. Hanghøj (2015) examined supplier evaluation based on delivery performance and capability. He emphasized that supplier delivery performance is an important metric when choosing a supplier because it can affect a company's competitive advantage (Hanghøj, 2015). This project evaluates delivery performance from the perspective of the supplier. NAVSUP GLS AMMO is concerned with the metric of delivery performance because it enables warfighters to effectively plan major logistical evolutions and sustain operations without interruptions.

Guiffrida, Jaber, and Rzepka (2008) proposed that delivery performance be quantified financially in order to evaluate its impact on the supply chain. Sopenberg, Land, and Gallman (2011) presented a framework for diagnosing delivery performance in make-to-order companies. In this project, delivery performance is evaluated by the ability of the system to meet the required delivery date of the customer based on historical data. This project does not seek to quantify the delivery performance in monetary terms. Rather, the simulated delivery performance is used as risk management information to ground future decision-making processes.

D. CONCLUSION

The literature suggests that stock positioning decisions are often driven by their cost-savings potential but neglects the effect that stock positioning may have on delivery performance. Some literature stresses the importance of delivery performance and offers methods to measure it. The analysis in this project simulates both the costs associated with repositioning the ammunition stockpile and the effect that it might have on the delivery performance of the supply chain. NAVSUP GLS AMMO may face a trade-off between cost and delivery performance with the decision if they decide to implement either system, or maintain the status quo.

III. METHOD

A. OVERVIEW

This chapter describes the overall goal of the model and how it shaped some of the decisions in the research process. It then discusses the process of collecting the demand variables and parameters and how that information was used to create distributions to support a Monte-Carlo simulation. This chapter concludes by describing how the rates were integrated into the model by walking through the step-by-step function of the model.

B. DESIRED GOAL OF THE MODEL

The goal of the model is to determine the cost and delivery performance risk when changing the stock positioning system of the ammunition supply chain. The model estimates two probabilities: (1) the probability of Navy's operating costs increasing and (2) the probability of delivery performance degrading when the system is changed from the status quo. The status quo system is depicted in Figure 1 and represents how ammunition is currently stored throughout the Navy's supply chain for ammunition that is not excluded by the DODD 5160.65. With the current system, some inventory is stored inland with the Army and some inventory is located closer to the customer, near the coast. The output of the model reveals the cost and delivery performance risk of converting to the following systems:

- A centralized system: The Army stores all ammunition waiting to be requisitioned by Navy customers at an inland depot (see Figure 2).
- A decentralized system: The Army sends the Navy's entire inventory to the coastal NMCs after they acquire the ammunition from the manufacturer. The Army no longer stores Navy ammunition (see Figure 3).

Figure 1. Depiction of the Status Quo System.

Figure 2. Depiction of the Centralized System.

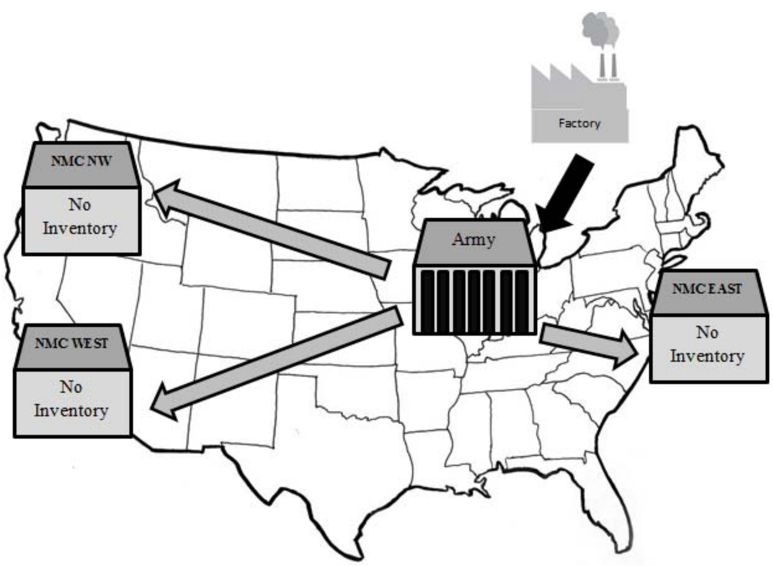
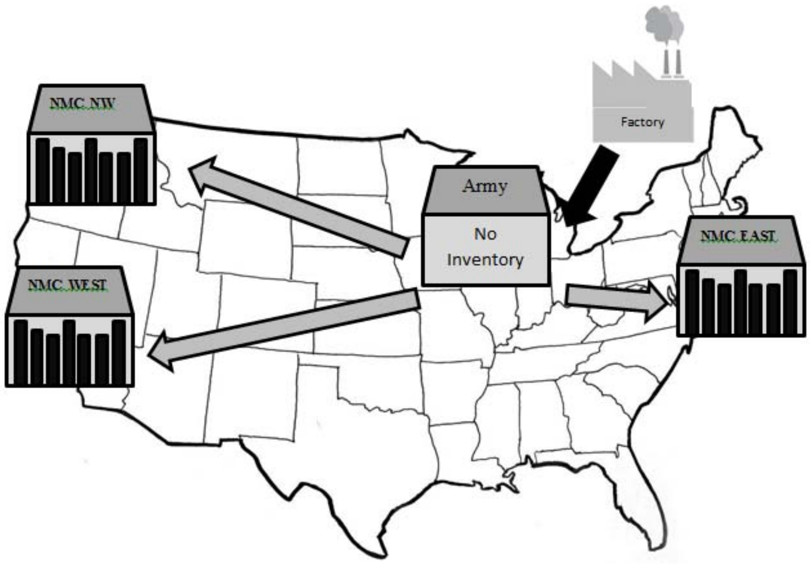


Figure 3. Depiction of the Decentralized System.



This project is focused on three NMCs (East, Northwest, and West) and their function in supplying two specific COGs of ammunition (2E and 2T). It compares the cost and delivery performance under each system shown in Figures 2 and 3 to the status quo.

C. DATA ANALYSIS AND RELEVANT METRICS

This section describes each rate and measurement that was extracted from the data sourced from NAVSUP GLS AMMO.

1. Determining the Time Frame of Data

The model simulates the distribution of possible outcomes of one hypothetical year of supply chain operations while considering the wide spectrum of operational build-ups and draw-downs that NAVSUP has to support. A simulated year would provide NAVSUP GLS AMMO flexible options when using the results for their tailored analysis. The model was developed using demand data from the last seven years because of the wide spectrum of operational requirements in that time frame. During that time, the military experienced ramped-up requirements from the surge of operations in Afghanistan down to moderate-to-low demands, with minimal involvement in Iraq and Afghanistan. This project focuses on the Continental United States (CONUS) aspect of the Navy ammunition supply chain, capturing any residual effects that operational demands indirectly placed on the Navy's CONUS supply chain. It is not the intention to identify the statistical correlation that war has on demand patterns in CONUS, but to include any effects on CONUS demands that might be in the data.

2. Narrowing the Scope to Specific Cognizance Symbols

For a COG to have met the initial criteria of suitability for this project, the total number of requisitions that each COG had sourced by the Army in the past seven years had be enough to provide an approximate delivery performance parameter within a 95% confidence level (α) with an error of estimation of 2% (B). A preliminary analysis revealed that not all eight COGs had a sufficient number of requisitions to statistically support strong distributions for both Army and Navy delivery performance.

In using Equation 1 (Keller, 2009, p. 340), it was assumed that delivery performance, determined by the sourcing activity's ability to successfully meet the requesting activity's RDD, is binomial because RDD success can only have two outcomes: meeting or not meeting the RDD. Equation 1 was used to determine the minimum amount of Army-sourced requisitions (*n*) that a COG would have to contain in the seven years to be an eligible candidate for this analysis. The approximate Army population average RDD success rate for all-time was around 10% ($\hat{\rho}$) with a 2% Error of Estimation (B). Table 2 depicts the breakdown of total requisitions for all COGs for seven years.

$$n = \left(\frac{z_{\alpha} \sqrt{\hat{\rho}(1-\hat{\rho})}}{\mathrm{B}} \right)^2 \tag{1}$$

$$n = \left(\frac{1.96\sqrt{.10(1-.10)}}{.02} \right)^2 = 864 .$$

Table 2. Total Requisitions for Each COG from 2008 to 2014.

		Source of Supply		Percentages	
COG	**Grand Total**	**Army**	**Navy**	**Army**	**Navy**
2D	1,900	0	1,900	0%	100%
2E	16,719	5,211	11,508	31%	69%
2T	68,710	10,929	57,781	16%	84%
4T	4,598	20	4,578	0%	100%
6T	696	64	632	9%	91%
8E	2,882	450	2,432	16%	84%
8T	3,920	37	3,883	1%	99%
8U	1,705	446	1,259	26%	74%

As shown in Table 2 in the "Army" column of "Source of Supply," 2E and 2T were the only COGs that exceed the 864 sample size needed to statistically reveal the delivery performance for the Army. If any other COGs were used in this analysis, it would have proven difficult to replicate the Army's delivery performance; samples smaller than 864 would have predisposed the model to reveal overly optimistic or extremely disappointing delivery performance. It was decided that this project would focus only on COGs 2E and 2T.

3. Selecting the Facilities to Study

It was predetermined that the model would analyze the demand of NMCs from different regions. Initial research revealed that the Navy frequently used site-to-site transfers that would often span across CONUS. The model needed to capture the costs that occurred because of the geographical distance between facilities. The scope of this project does not involve finding the exact correlation between location and the outputs, but to verify whether or not stock positioning plays a significant role in cost. It was decided that using one NMC from the West Coast, one from the East Coast and one from the northwest portion of CONUS would best represents all inter-NMC transactions.

For the purpose of this project, NMCs are referred to by their regional location (i.e., NMC East, NMC West, and NMC NW) instead of using their actual names. This is a precaution to avoid revealing sensitive information about individual Navy units' allocations and demand patterns, and to avoid inadvertently making it possible to extrapolate demand patterns for specific NMC customers.

Two models were designed for this project—one for 2E and one for 2T—to demonstrate how the three NMCs vary in cost and delivery performance when the systems are altered. The ammunition supply facility in Crane, Indiana will act as the inland Army depot for this project because the majority of 2E and 2T ammunition supplied by the Army comes from that facility.

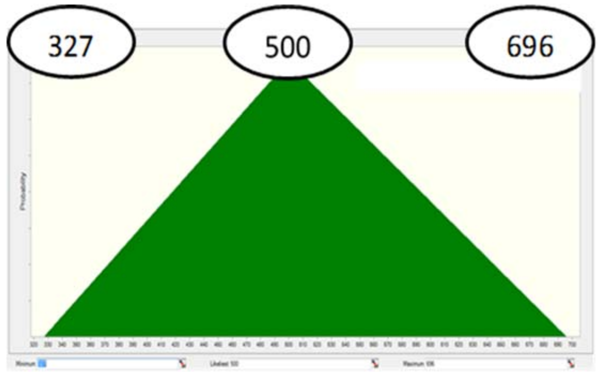
4. Determining Demand Distribution for Naval Munitions Commands

To estimate the cost to operate each system for one year, a Monte-Carlo simulation is used to generate demand data. A demand distribution for each GOG had to be input into the model to reflect actual supply chain behavior. The simulation quantifies (1) the amount of requisitions each NMC would process in a year and (2) the size of each requisition. This section describes how the demand distributions were determined for requisition quantity and tonnage.

a. Determining the Distribution of Requisitions for Each Naval Munitions Command

The data revealed the minimum, average, and maximum number of annual requisitions for each NMC and for each COG over seven years. A triangular distribution of demand for each COG was used to replicate the number of requisitions that each NMC might process in a hypothetical year. Using data from the last seven years ensures that the model realistically replicates historical demand conditions. As an example, Figure 4 depicts the triangular distribution that represents the annual amount of 2E requisitions that were processed through NMC East from 2008 to 2014.

Figure 4. Distribution of the Annual Amount of 2E Requisitions for NMC East, 2008 to 2014.



The x-axis corresponds to the number of requisitions (minimum value is 327, the average is 500, and the maximum value is 696) and the y-value corresponds to the probability of occurrence.

Based on data from the last seven years, NMC East processed, on average, 500 requisitions a year for 2E. In its slowest year, it processed 327 requisitions and, in its busiest year, it processed 696 requisitions. When the model simulates how many 2E requisitions NMC East might process, it generates a random variable that ranges between 327 and 696. The random variable, however, has a high probability (as shown by the peak of the triangle) of being around 500 requisitions and a low probability of being on the extreme ends of 327 or 696.

The Monte-Carlo simulation uses triangular distributions for each COG to randomly generate the requisition quantities for each simulated year from each NMC. Table 3 depicts the statistical inputs from the data that were used to develop the triangular distributions for each NMC.

Table 3. Inputs for the Annual Requisition Quantity Distributions.

		MIN	AVG	MAX
2E	NMC East	327	500	696
	NMC NW	174	337	698
	NMC West	105	164	191
2T	NMC East	895	1,205	1,746
	NMC NW	411	1,058	2,066
	NMC West	1015	1,217	1,422

b. Determining the Distribution of Tonnage per Requisition

After the model simulates the number of requisitions each NMC would process in a year, it randomly assigns the weight of each requisition in tons based on the historical distribution. Because the model assigns the source of supply for each requisition based on history, forcing each requisition to vary in weight facilitates realistic variability in how much weight each source provides annually. Using this method also captures the variability in costs to the NMCs as well, because each source of supply generates different handling and shipping rates for each ton of ammunition.

Triangular distributions were used for the requisition tonnages for each COG and NMC over the last seven years. For simplicity, the requisitions were not segmented into separate years. All seven years of requisitions were analyzed from each NMC by COG and distributed into one triangular distribution using the minimum, average, and maximum values. Table 4 depicts the statistical inputs that determined the triangular distributions for the requisition tonnage of each NMC and COG.

Table 4. Inputs for the Requisition Tonnage Distributions (Tons).

		MIN	AVG	MAX
2E	NMC East	0.001	16.350	543.202
	NMC NW	0.001	8.022	484.65
	NMC West	0.001	0.773	25.42
2T	NMC East	0.001	1.085	76.597
	NMC NW	0.001	0.865	54.066
	NMC West	0.001	0.967	15.35

5. Determining the Source of Supply Distributions

In the model, the source of supply distribution varies by system and location. The model determines the likelihood that each source of supply needs to fulfill a requisition in the status quo and it also determines the site-to-site source in the decentralized system when an order cannot be fulfilled by the resident stock. The source of supply distribution is based on how often each source was relied on over last seven years for each NMC. Under the decentralized system, it is assumed that 98% of orders would be sourced from the resident stock and no orders would be sourced by the Army—but the *relative* frequency with which each site-to-site source would be used is based on the historical source of supply distribution. Under the centralized system, all orders will be sourced by the Army.

Before simulating how the source of supply distributions would be used in a centralized and decentralized system, it had to be determined how each NMC was sourced in the past seven years under the Status Quo. The three NMCs' sourcing patterns for each of the seven years were analyzed and it was determined how often an NMC had its requisitions fulfilled from the following sources (using NMC West as an example):

- Directly from the Army's Inventory
- First-pass effective from its resident stock
- From another NMC in the same region/local site-to-site transfer
- From an NMC in the northwest/NW site-to-site transfer

- From an NMC in the east/east site-to-site transfer
- From an NMC in the southwest/SW site-to-site transfer

It is important to note that from this point, NMCs in the southeast will be mentioned in this project, but only in the context of acting as a supplier for the NMCs in question. The southeast NMCs did not have sufficient data to be useful as test subjects, but they did act as sources of supply for the three subject NMCs on some occasions, so their utility could not be ignored.

Table 5 shows how often each requisition was sourced from the Army for each COG on an annual basis. The complement percentage was used to determine how often the Navy sourced its own ammunition requisitions. The information in Table 5 was used to determine the minimum, average, and maximum statistics and to create triangular distributions for each NMC to enable the model to simulate how often the Army would source a requisition in the future.

Table 5. Annual Proportions Where the Army Was the Source of Supply.

		2008	2009	2010	2011	2012	2013	2014
2E	NMC EAST	22.02%	22.13%	22.69%	11.76%	25.44%	14.86%	24.76%
	NMC NW	39.38%	28.18%	22.49%	15.65%	18.83%	13.22%	13.37%
	NMC WEST	10.29%	13.38%	5.46%	8.38%	5.79%	22.76%	15.24%

		2008	2009	2010	2011	2012	2013	2014
2T	NMC EAST	8.37%	7.45%	9.81%	8.95%	11.13%	5.88%	20.67%
	NMC NW	15.71%	13.34%	10.31%	6.35%	5.23%	9.25%	4.65%
	NMC WEST	16.83%	25.50%	21.73%	8.80%	9.12%	12.91%	11.20%

Table 6 shows how often an NMC sourced its own requisitions from its resident inventory. The results were organized as the minimum, average, and maximum annual proportions depicting how often a particular source was used by each NMC for each COG.

Table 6. Statistics Used to Create Navy Resident-Sourced Distributions.

		MIN	AVG	MAX
2E	NMC EAST	83.97%	88.45%	91.43%
	NMC NW	77.01%	86.26%	96.94%
	NMC WEST	68.38%	76.61%	87.86%

		MIN	AVG	MAX
2T	NMC EAST	91.22%	94.70%	96.77%
	NMC NW	84.62%	88.21%	91.93%
	NMC WEST	75.90%	79.25%	83.68%

Table 7 depicts the statistical information used to develop the 2E and 2T triangular distributions of intra-Navy site-to-site transfer sourced requisitions. The values are used in the model to allow it to determine from where a requisition will be sourced if it is determined to be not sourced by the Army or by the resident stock of the local NMC.

Table 7. Statistical Information Used to Develop the Navy Site-to-Site Navy Source Distributions.

	NMC EAST	**MIN**	**AVG**	**MAX**
2E	Local (East) Region Site-to-Site	76.74%	86.41%	95.83%
	NW Site-to-Site	0.00%	0.00%	0.00%
	SE Site-to-Site	0.00%	0.63%	2.33%
	West Site-to-Site	2.08%	12.96%	20.93%
	NMC NW	**MIN**	**AVG**	**MAX**
	Local (NW) Region Site-to-Site	0.00%	6.88%	33.33%
	East Site-to-Site	0.00%	21.07%	66.67%
	SE Site-to-Site	0.00%	0.00%	0.00%
	West Site-to-Site	0.00%	72.05%	100.00%
	NMC WEST	**MIN**	**AVG**	**MAX**
	Local (West) Region Site-to-Site	74.36%	84.46%	100.00%
	East Site-to-Site	0.00%	2.65%	7.69%
	SE Site-to-Site	0.00%	0.00%	0.00%
	NW Site-to-Site	0.00%	12.88%	23.08%

	NMC EAST	**MIN**	**AVG**	**MAX**
2T	Local (East) Region Site-to-Site	85.96%	94.55%	100.00%
	NW Site-to-Site	0.00%	0.90%	2.46%
	SE Site-to-Site	0.00%	2.38%	4.88%
	West Site-to-Site	0.00%	2.17%	10.53%
	NMC NW	**MIN**	**AVG**	**MAX**
	Local (NW) Region Site-to-Site	1.47%	7.96%	23.91%
	East Site-to-Site	0.77%	1.90%	2.61%
	SE Site-to-Site	0.00%	0.00%	0.00%
	West Site-to-Site	73.91%	90.15%	97.06%
	NMC WEST	**MIN**	**AVG**	**MAX**
	Local (West) Region Site-to-Site	71.25%	80.53%	90.14%
	East Site-to-Site	0.00%	2.70%	8.75%
	SE Site-to-Site	0.00%	0.06%	0.44%
	NW Site-to-Site	9.79%	16.71%	24.71%

6. Determining Shipping Distances for All Shipments

A key assumption of the model is that the Army always procures and possesses the ammunition first. This means that the Army always has to ship ammunition to the

Navy in each system. The Navy does not have the option to get ammunition directly from the manufacturer.

The delivery performance used in the model is influenced by the specific source and its associated historical performance. Distances alone did not seem to correlate to better or worse delivery performance in the Navy supply chain overall, so distances were used only to determine costs.

The distances for shipments were measured in driving miles because most ammunition in the Navy is delivered by truck. The distances in the model do not simply represent the one-way distance between the source of supply and the receiving NMC; the input data is a little more nuanced than that. The mileage that was measured is the total distance that a specific lot of ammunition had to travel—starting from the Army facility in Indiana—before it got to the final NMC where it is received by a Navy customer. For example, if a batch of ammunition is delivered to NMC West as a site-to-site transfer from NMC East, the total assumed distance it would have traveled is the total distance from the Army depot in Crane, Indiana, to NMC East and then to NMC West. The full, systematic expenditures of site-to-site transfers must be captured because they represent stock not positioned where it is needed.

One consideration that complicated shipping distances was that more than one Navy facility can be a possible source in each region. So, to capture this variability in the model, the mileage calculated for each NMC is not the exact mileage from one specific facility in the source region. The average distance that a shipment from a specific region would travel from the top two to three most active NMCs or Navy facilities in that region was calculated. It is rare that the same facility would source all interregional, site-to-site transfers every year. There are usually two to three activities that pitch in to supply ammunition to other regions.

Factoring the average distance prevented the need to develop additional distributions and simulations that would determine what specific facility sourced a site-to-site transfer. Table 8 depicts the driving distances used for each source region. The mileage is multiplied by the tonnage of the requisition to determine shipping costs.

Table 8. Driving Distances (Miles) Used in Simulation Model.

Source of Supply	Driving Mileage	Destination
Local (East) Region	1,147	NMC East
West Region	3,607	
Southeast Region	1,585	
Northwest Region	3,419	
Army (Crane, Indiana)	671	
Source of Supply	**Driving Mileage**	**Destination**
Local (NW) Region	2,386	NMC NW
East Region	5,341	
Southeast Region	5,417	
West Region	3,550	
Army (Crane, Indiana)	2,340	
Source of Supply	**Driving Mileage**	**Destination**
Local (West) Region	1,909	NMC WEST
East Region	4,425	
Southeast Region	4,201	
NW Region	2,971	
Army (Crane, Indiana)	2,071	

7. Determining Required Delivery Date Success Rate Distributions

Delivery performance is measured by the sourcing activity's ability to successfully deliver a requisition on or prior to the requesting activity's RDD. The RDD success rate is the ratio of successful deliveries for a given time period. To simulate the Army and Navy's delivery performance for one year, each service's historical RDD success rate over seven years was used. For the Navy, RDD success was separated into the following categories: (1) the proportion of times the Navy met the RDD when a requisition was sourced by the resident inventory of the local NMC and (2) the proportion of times RDD was met with site-to-site transfers. For the Army, the overall annual performance was used. The analysis resulted in the following three RDD success rate distributions for each NMC under both COGs: (1) the probability of RDD success for the Army overall; (2) the probability of Navy RDD success for requisitions sourced by local NMC inventories; and (3) the probability of Navy RDD success for site-to-site transfers.

RDD success was stated explicitly in the data provided by NAVSUP GLS. A column indicated—with a Yes or No entry—whether or not a requisition met the RDD. Table 9 depicts the statistical data that was used to develop the triangular RDD success rate distributions used by the model for all three NMCs and for both COGs.

Table 9. Statistical Information Used to Develop RDD Success Rate Distributions for 2T and 2E.

	2E				2T			
	SOS	**Min**	**Average**	**Max**	**SOS**	**Min**	**Average**	**Max**
NMC EAST	**Resident**	0.00%	0.55%	2.22%	**Resident**	0.50%	1.48%	2.93%
	All S2S	0.00%	4.32%	12.96%	**All S2S**	0.00%	14.26%	44.44%
	Army	2.60%	10.72%	39.81%	**Army**	1.22%	19.20%	81.08%
NMC NW	**Resident**	4.38%	9.88%	18.77%	**Resident**	1.32%	5.55%	8.87%
	All S2S	4.17%	8.96%	20.83%	**All S2S**	2.66%	17.36%	61.42%
	Army	0.00%	6.07%	11.11%	**Army**	4.69%	14.99%	25.37%
NMC WEST	**Resident**	0.66%	7.70%	13.18%	**Resident**	0.93%	6.80%	16.28%
	All S2S	7.69%	15.37%	22.64%	**All S2S**	5.98%	12.09%	19.25%
	Army	0.00%	11.69%	23.81%	**Army**	6.25%	21.38%	53.13%

8. Information Not Included in the Data

To build a model that has utility to NAVSUP GLS, some rates needed to be determined that were not available in the data provided. This section discusses the rates that were provided by NAVSUP GLS AMMO and the rates that were estimated.

a. Handling Rates

NAVSUP GLS AMMO provided the per-ton handling rates for the majority of the NMCs in CONUS. Those rates were used to determine the average handling cost for the busiest 2–4 NMCs in each region. These averages were used to develop the total handling rates for each possible source region and NMC destination. Table 10 depicts the handling rates (per ton) that were used for each NMC, broken down by source-of-supply. Included in each rate is the individual handling rate for every Navy facility that would handle the ammunition, to include the final destination NMC.

Table 10. Handling Rates for Each NMC, Based on the Source of Supply for a Requisition.

Source of Supply	Cost per Ton	Destination
Resident Stock	$136	NMC EAST
East (Local) Region	$450	
Northwest Region	$458	
Southeast Region	$554	
West Region	$1,124	
Source of Supply	**Cost per Ton**	**Destination**
Resident Stock	$60	NMC NW
Local (NW) Region	$582	
East Region	$284	
Southeast Region	$478	
West Region	$1,048	
Source of Supply	**Cost per Ton**	**Destination**
Resident Stock	$101	NMC WEST
West (Local) Region	$1,329	
East Region	$325	
Southeast Region	$519	
Northwest Region	$421	

For example, suppose the simulation assigns a requisition for NMC East to be fulfilled by a West Region NMC. The model multiplies the weight of the requisition by $1,124 (see Table 10) to determine the total handling charges that the Navy incurred for that requisition. Included in that $1,124 rate are the following other rates:

- The average handling rate ($494) for the West Coast region is included because the ammunition supplied was originally sent to the West Coast by the Army to be used as West Coast inventory.
- The average handling rate for the West Coast ($494) is included again because the NMC from the West Coast had to handle and prepare the ammunition a second time to send it to the East Coast.
- The handling rate ($136) for NMC East is added because it had to handle the ammunition to receive it from the West Coast.

The resulting sum of the three rates is $1,124. This method of handling rate development was used to capture the systematic costs for the Navy for not positioning stock at the correct point-of-need the first time. In the model, the receiving NMC is assigned all prior handling charges for site-to-site shipments to capture the inefficiencies of site-to-site transfers and input a penalty for those inefficiencies.

On a final note, two important assumptions that are in the model must be highlighted: (1) When the Army handles ammunition, it does not charge the Navy a handling cost and (2) an NMC incurs its own handling costs when it receives a return of ammunition from its customer. The Army does not currently charge handling costs now and that assumption is used throughout this entire project. The last point will be covered in the next section.

b. Material Returns

It is common practice for Navy customers to return unexpended ammunition after a deployment. In the status quo and decentralized systems, offloaded ammunition will either be given to other customers or put back in the NMC inventory. Either way, returned ammunition will incur handling charges for all systems, but in the centralized system it will also incur additional shipping charges because all returns will be shipped back to the Army. Instantly returning ammunition to the Army is an assumption that was agreed on with the sponsors (J. M. Bolig, personal communication, September 30, 2015), and it reflects how NMCs would serve as cross-docks in the centralized system.

To capture all costs, it had to be determined or assumed how much ammunition was returned in the past. NAVSUP GLS AMMO provided the actual tonnage of ammunition returned to the subject NMCs in one specific year, and that amount was compared to the total tonnage that was requested in that same year. By analyzing what was returned in comparison to what was requested in total, it was possible to use a baseline return rate to estimate reality. It may not be an accurate rate across time, but it serves as the benchmark for returns in the model. Table 11 shows the return rates used in the model.

Table 11. Ammunition Return Rates Used in the Simulation Model.

	2E	2T
NMC EAST	54%	38%
NMC NW	61%	37%
NMC WEST	58%	54%

c. Shipping Rates

NAVSUP GLS AMMO provided the estimated cost to ship one ton of 2E and 2T per mile. These costs were applied as constants, as per the expert opinion of NAVSUP GLS AMMO. In the model, it costs the Navy $0.40 and $1.66 to ship one ton of 2E and 2T per mile, respectively (J. M. Bolig, personal communication, October 9, 2015).

d. Holding Costs

NAVSUP GLS AMMO provided the holding costs for each of the NMCs for one fiscal year. Table 12 shows the holding costs used for both COGs as a constant for the status quo system simulations. This is obviously an approximation; holding costs vary with shipments and inventories. For the purpose of this project this approximation was deemed sufficient.

Table 12. Holding Costs per Facility.

	Holding Costs
NMC East	$3,714,029
NMC NW	$1,379,854
NMC West	$1,259,392

When simulating the centralized system, all holding costs are removed from the NMCs because (1) the NMCs would not hold inventory and (2) it is assumed that the Army would not charge the Navy a holding cost to centrally store the Navy's ammunition (J. M. Bolig, personal communication, September 30, 2015).

When simulating the decentralized system, the holding cost is increased by the same percentage that the NMCs in question improve their first-pass effectiveness. The assumption is that any increase in first-pass effectiveness is due to more inventory being held at the NMC level. This is a conservative assumption, because it assumes the increase in safety stock is only what is actually needed for the performance that is attained (no extra safety stock because the system is decentralized). For simplicity, it is assumed that the increase in inventory will be proportionate to the increase in an NMC utilizing its resident stock.

e. Setup Costs for the Centralized System

To analyze the three NMCs under a centralized system, the model uses fixed set-up costs provided by NAVSUP GLS AMMO. This cost is calculated based on the amount of inventory that would be re-positioned at the Army depot from each NMC. In the simulation, when the Navy and the Army agree to move to a centralized system, the ammunition stored by the Navy would be immediately returned to the Army for storage. All NMCs would serve as quasi cross-docks and thus have to forfeit all inventories to the Army immediately. The set-up costs would represent the shipping and handling costs that the Navy would incur by sending the ammunition back to the Army. The model uses the inventory levels provided by NAVSUP GLS to formulate shipping and handling costs to get the ammunition back to Crane, Indiana. No set-up costs are relevant in the other systems and the rationale will be explained further in the model design section.

Table 13. Set-Up Costs Used for Each NMC under the Centralized System.

	NMC EAST	NMC NW	NMC WEST
2E	$2,264,640	$2,988,000	$65,058
2T	$2,499,720	$4,654,392	$10,262,694

D. MODEL DESIGN

This section discusses the output of the model and its operation from step one through the final step. A Monte-Carlo simulation is used to generate demand, source of supply distribution, site-to-site source location and delivery performance. Embedded in the step-by-step descriptions are explanations of some of the policies that may have shaped the behavior of the model.

1. The Output of the Model

After the model runs one simulated year (one iteration), the output of the model is:

- The distribution of net costs: when total costs of the centralized system are subtracted from the total costs of the status quo system for each COG.
- The distribution of net costs: when the total costs of the decentralized system are subtracted from the total costs of the status quo system for each COG.
- The distribution of net RDD success rates: when the RDD success rate for the status quo is subtracted from the centralized system RDD success rate for each COG.
- The distribution of net RDD success rates: when the RDD success rate for the status quo is subtracted from the decentralized system's RDD success rate for each COG.

A positive net cost or positive net RDD success rate in either output indicates that the status quo system would be less costly and have an improved delivery performance. The model computes this output by calculating total cost and delivery performance for every NMC, under each system, for both COGs. A simulation of the net costs and net RDD success rate of the systems for each COG is run 10,000 times to provide a distribution of net costs and net RDD success rate at a 95% confidence level.

2. Sequence of Simulations and Calculations in the Model

For simplicity, one COG model, performing one simulated year, is used to explain the sequence of the model. The model tests the three systems on each of the three NMCs under one COG by running thousands of one-year simulations to develop a confidence interval of simulated costs and delivery performance. In the subsequent Results chapter of this paper, the output of this model is revealed.

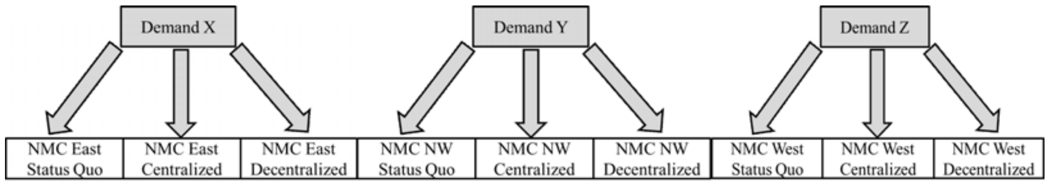
a. Establishing Demand Levels

The first step of the model is establishing the baseline demand by simulating the number of requisitions that each NMC will process that year. The baseline number and weight of requisitions will be different because each NMC has a different distribution for number and tonnage of requisitions. The statistics in Table 3 are used to feed the model to assign each NMC a quantity of requisitions via Monte-Carlo simulation.

Once the number of requisitions is established, the model analyzes each requisition for each NMC and assigns a requisition tonnage based on each NMCs' requisition tonnage distribution set by the statistics from Table 4. By the time the baseline demand is set for each NMC, the model will know each NMCs' requisition quantities and tonnages.

It is important that each system for each NMC to be measured on the same level of demand, so that costs can be compared side-by-side. Hence, common random numbers are used for each scenario. For one COG model, three different demand levels are automatically determined by the model for each NMC, but the same demand is applied to each scenario (they are run simultaneously). Every time a new year is simulated, new demand levels are determined for each NMC. Figure 5 gives a graphical explanation of how demand is constant for each NMC.

Figure 5. Depiction on How Demand Levels Are Used in One COG Model Each Year.



b. *Source of Supply Determination*

This subsection discusses how the model determines the source for each requisition. Every requisition for an NMC is assigned a source of supply through a multilayered, Monte-Carlo simulation that is explained below.

(1) The Overall Sourcing Probabilities that Influence the Model

When a new year is simulated in a COG, each NMC is given a source of supply distribution based on the statistics that were discussed. Each NMC has a Monte-Carlo simulation that varies slightly for each system. The difference in the source of supply distributions across systems is whether or not the Army or the local NMC can serve as a source of supply.

Using the status quo system as an example, the source of supply distribution produced through simulation will reveal the following rules of the model:

- The probability that a requisition is supplied by the Army
- The probability of a Navy-supplied requisition being fulfilled by the resident inventory of the NMC

Once these variables are determined, the complements of these percentages implicitly reveal the probability of a requisition being sourced by the Navy as a whole, and the probability that a requisition sourced by the Navy would be supplied with a site-to-site transfer.

When the model simulates a centralized system for each NMC, the probability of each requisition being sourced by the Army is 100%, as it is the only location available to supply requisitions. Under the decentralized system simulations, the probability of a requisition being supplied by the Army is 0% and a carefully considered percentage is injected into the model that determines the probability that an NMC can source its own requisitions.

(2) Determining the Probability for Each Site-to-Site Source Location

After the model determines the Army sourcing probability and the resident sourcing probability, the model generates another distribution that determines the probabilities of each site-to-site location being used as a source. The model was developed to determine site-to-site probabilities by using the distributions from all past site-to-site transfers depicted by the statistics in Table 7. This ensures that the site-to-site sources follow a similar pattern experienced in the last seven years.

The model generates the probabilities of site-to-site locations so that cumulatively, all site-to-site location probabilities add up to 100%. To ensure this happens, the model was designed to take the difference in cumulative probabilities from 100% and spread it proportionately across all site-to-site locations, adding or subtracting as necessary. Once the model determines that a requisition is sourced by a site-to-site transfer, the cumulative probabilities of all site-to-site locations must equal 100%. Simply determining the last location's demand by subtracting from 100% would have created a correlation between demands, and would not have solved the problem of what to do when the initial sites totaled more than 100%. When the probabilities are proportionately adjusted, a correlation is not injected into the original simulation outputs.

Table 14 depicts the steps the model takes once the Monte-Carlo simulation determines the assigned probabilities for site-to-site locations. Column two shows how the simulation provides unrefined, independent probabilities (in descending order) for each source of supply that do not necessarily add to 100%. Column three shows how the model automatically refines the probabilities by adding or subtracting proportional changes to each source of supply to have the probabilities all add up to 100%. The model then calculates the cumulative values of the probabilities (see column four, Table 14) and then it creates probability intervals (see column five, Table 14). This process is repeated for every simulated year, for every NMC and every system.

Table 14. Example of How Site-to-Site Probabilities are Manipulated in the Model, Using NMC East as an Example.

Site-to-Site Source	Unrefined Assigned Probability	Refined Assigned Probability	Cumulative Value	Probability Interval
Regional	45.00%	50.00%	50.00%	0-50%
West	22.50%	25.00%	75.00%	51%-75%
Northwest	13.50%	15.00%	90.00%	76%-90%
Southeast	9.00%	10.00%	100.00%	91%-100%
Total	**90.00%**	**100.00%**		

For each requisition in the simulation, the following sequence of events occurs to determine the source of supply:

- The model references the given probability of a requisition coming from the Army and generates a [0, 1] uniform random variable. If the random variable generated is less than or equal to the probability of the Army serving as a source of supply, then the model declares that requisition to be Army-sourced. If the random variable exceeds the probability of the Army serving as the source, the model determines the Navy to be the source of supply and moves on to the next step.

- The model then generates another [0, 1] uniform random variable and compares it to the probability that an NMC will fulfill a requisition with its resident inventory. If the random variable generated is less than or equal to the probability of an NMC using its resident stock to fulfill a requisition, the model determines that the requisition was fulfilled by the NMC's resident stock. If the random variable exceeds the probability of an NMC resident stock fulfillment, then the model determines that the particular requisition must be fulfilled by a site-to-site transfer and moves on to the next step.

- The model then generates another uniform random variable between 0.00 and 0.99 and compares it to the probability intervals of the site-to-site transfers (as in column five, Table 14). Regardless of what random variable is generated, it will fit within one of the assigned probability intervals generated by the model. Whichever corresponding interval the random variable lies within is the source of supply for that specific requisition.

The steps just mentioned are repeated for every requisition for each NMC under each system, with small changes to account for the different structures in the centralized and decentralized systems. For a centralized system, the first step automatically determines that all requisitions are sourced from the Army and no other steps are conducted. For the decentralized system, the first step automatically assumes that all requisitions are sourced from the Navy and the subsequent steps are the same as above, as site-to-site transfers are still possible.

c. Determining Total Cost

The previous steps determine the number of requisitions each NMC will process for each system, the size of each requisition (and thus the total tonnage), and the source of supply. The model is then ready to determine all the costs to operate the NMCs in each system.

(1) Handling and Shipping Costs for Requisitions

The model determines the total handling costs based on the rates listed in Table 10. It automatically factors in the handling rates of the source and the NMC receiving the ammunition. Additionally, the model determines the shipping costs for each individual requisition. The shipping costs are calculated in the model by multiplying the shipping rates by the tonnage for that specific requisition and by the average distances between each region. Then, the cost to fulfill the requisitions for every NMC is known. The model, however, has not calculated the cost to handle returns and the set-up costs in a centralized system.

(2) Holding Costs

Holding costs vary between system types and NMCs. For the status quo system, the rates provided by NAVSUP GLS AMMO are used. For the centralized system, holding costs are assumed to be zero, as the Army is assuming all holding costs. For the decentralized system, holding costs are increased—from the status quo holding costs—by the difference in percentage that it sources more of its requisitions from its resident stock.

Using the NMC East model as an example, if the status quo system sources 50% of its Navy-supplied requisitions from resident stock and the decentralized system sources 80% of its Navy-supplied requisitions from the resident stock, then the holding costs are increased by 30% from the status quo holding costs (80%–50%) in the decentralized system.

(3) Determining the Cost of Returns

The model also estimates the percentage of ammunition that is returned to the NMC for each year. Based on a fixed percentage, the model determines how much shipping costs and handling costs have increased due to returns. For all three systems, the NMC incurs a handling cost for the operation of receiving the ammunition and/or sending it back to the Army. Either way, a customer return incurs the resident handling rate per ton for each NMC. In the centralized system, all ammunition offloaded returns to the Army depot and incurs shipping costs. All other systems do not incur a shipping fee for returns.

(4) Determining Set-Up Costs

In the centralized system, set-up costs are calculated into the total costs. The model automatically calculates the costs of repositioning the NMCs' stockpiles to the inland Army depot using the shipping and handling rates provided by NAVSUP GLS AMMO. After set-up costs are calculated, the cost for each NMC to handle requisitions and returns under their respective systems can be determined. The model can now get the total costs for each NMC under each system.

Set-up cost is not relevant in the decentralized system because it is assumed that no additional costs will be incurred to position stock at the coastal areas of CONUS. The model already accounts for the cost of shipping ammunition from the Army to the NMCs in the decentralized system. Even if the Army transferred a bulk of ammunition to the NMCs at the onset of the decentralize policy change, the movement of the ammunition would cost the same as if the ammunition was moved in smaller lots over a period of time. Essentially, the model captures the movement of ammunition from the Army to the

NMCs no matter when it moves and it costs no more than it does in the centralized and status quo systems.

d. Determining Delivery Performance

In the next step, the model determines how successful each NMC is at meeting its RDDs in each system.

(1) Setting the Delivery Performance Baseline for the Year

Using the statistics from Table 9, a Monte-Carlo simulation provides three variables for each NMC that represent the probability of RDD success for the year. The three separate metrics describe the probability of RDD success for (1) Army-sourced requisitions; (2) NMC, resident-inventory-fulfilled requisitions; and (3) Navy-fulfilled, site-to-site requisitions. These established benchmarks act as a guide for each sources' delivery performance, but do not necessarily ensure that the actual requisitions will all average out to those RDD success probabilities.

(2) Determining the Individual Required Delivery Date Success for Each Requisition

Once the source of supply is identified for an individual requisition, the model references the corresponding RDD success rate set as a benchmark for that specific type of source of supply. The model then generates a [0, 1] uniform random variable. If the random variable is equal to or less than the probability of meeting the RDD for that particular type of source, the requisition is deemed to have met the RDD. If the random variable exceeds the probability of the RDD being met for that type of source, then the requisition is determined as having missed the RDD. This method allows the model to determine delivery performance fairly based on the past merits of each type of source in the last seven years.

e. Determining Net Cost and Net Required Delivery Date Success Rates

The final step of the model is to take the total costs and RDD success rates of each system, and provide an output of net cost and net RDD success rate. This section describes how the model combines all that information to provide the net metrics for one year.

(1) Determining the Net Costs

Once the model has determined the total costs for each NMC under each system, it then determines the net costs for what it would cost the Navy to run different systems, compared to the status quo. The model takes the total costs of the centralized and decentralized systems separately and subtracts them from the total cost of the status quo system.

For example, if the status quo system had a total cost of $1 million (M), the centralized system had a total cost of $2M, and the decentralized system had a total cost of $800,000. The centralized system would have a net cost of –$1M ($1M–$2M) and the decentralized system would have a net cost of +$200,000. A negative net cost for the centralized system indicates that the centralized system is more expensive to run under similar conditions and a positive net cost indicates that the decentralized system is cheaper.

(2) Determining the Net Required Delivery Date Success Rates

Conversely, the model takes the average RDD success rate from the status quo system and separately subtracts it from the decentralized and centralized system's average RDD success rates. A negative net RDD success rate would indicate that the status quo's delivery performance was better in comparison to the centralized or decentralized systems.

E. CONCLUSION

This chapter discussed how all the data was used in the model and how the model can provide the sponsors with cost and delivery performance comparisons at the COG level under the three different systems. A one-year COG simulation was used to walk through the steps of the model and to describe how the model uses variability to simulate one year. The intention of this project is not to predict what actual costs and delivery performance would be, but to show how each system could perform compared to the status quo.

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IV. RESULTS

A. OVERVIEW

This chapter discusses the results of the model simulation that was run for each system, the pertinent factors that influenced the results, and the observed changes in the results after conducting sensitivity analysis. This chapter also describes the average cost savings and delivery performance improvement for each system as well as the risk of cost increase or delivery performance degradation.

B. RESULTS FROM THE MODEL

For both the net cost and net RDD success rate, the averages are calculated with a 95% confidence interval and, because 10,000 iterations were run for each simulation, a tight range of intervals can be provided for the means calculated. This information would help NAVSUP GLS AMMO see a realistic expected range of average cost savings and delivery performance improvement, based on the data provided. This chapter further explains how the intervals were calculated and what they mean.

Because independent models were used for each COG, their results are discussed separately. The term “risk” will be used when describing the results. Risk is defined as the probability of experiencing increased cost or delivery performance degradation when converting to a decentralized or centralized system from the status quo system. The output of the model is a distribution of net cost and net RDD success rate for both COGs and both systems. The value at risk for each distribution is the percentage of the results below zero, which indicates the risk that the system would experience increased cost or degraded delivery performance when changed from the status quo.

In determining the risk of cost increase, the output of the model is a distribution of the individual net difference of costs when the decentralized and centralized systems are each separately compared to the status quo system for one year. If the net difference of cost is positive for a particular system in a given year, it means that it would have saved the Navy money to use the system being compared to the status quo. The model finds this net difference for 10,000 iterations/simulated years and outputs a distribution that determines the number of times, out of the 10,000 iterations, that the alternate stock positioning system costs more than the status quo system. This process helps reveal the probability that an alternate stock positioning system would cost more than the status quo and thus determine the level of cost risk that is involved with converting away from the status quo. The model conducts this process with both stock positioning systems, for both COGs.

To determine the risk of delivery performance degradation, the metric net RDD success rate is used. Similarly to determining cost risk, the model individually compares the alternative systems' RDD success rate for one year against the status quo success rate. The RDD success rates—expressed as a the percentage of the time that the RDDs are met by the sourcing activity—are compared against each other for one year and the result is a net RDD success rate distribution. If the value of the net RDD success rate is positive, then the RDD success rate would have been higher—by the stated percentage—if the stock positioning system being compared (decentralized or centralized) to the status quo was used instead. Again, the model conducts this process for 10,000 simulated years and develops a net RDD success rate distribution that reveals the probability that the net RDD success rate is negative and, thus, it will reveal the risk of having delivery performance degraded if the Navy switched to a decentralized or centralized system.

First, the results of COG 2E are discussed, followed by the results of COG 2T. After describing the results of each COG, comparisons are made to identify the peculiarities of each COG's behavior. To reclarify the metrics of the output, if any COG has a positive net cost or positive net RDD success rate in comparison to the status quo, it is considered superior in cost or delivery performance to the status quo.

1. Cognizance 2E Results

For COG 2E, this section describes the results of the centralized system, followed by the results of the decentralized system.

a. 2E Centralized System Results

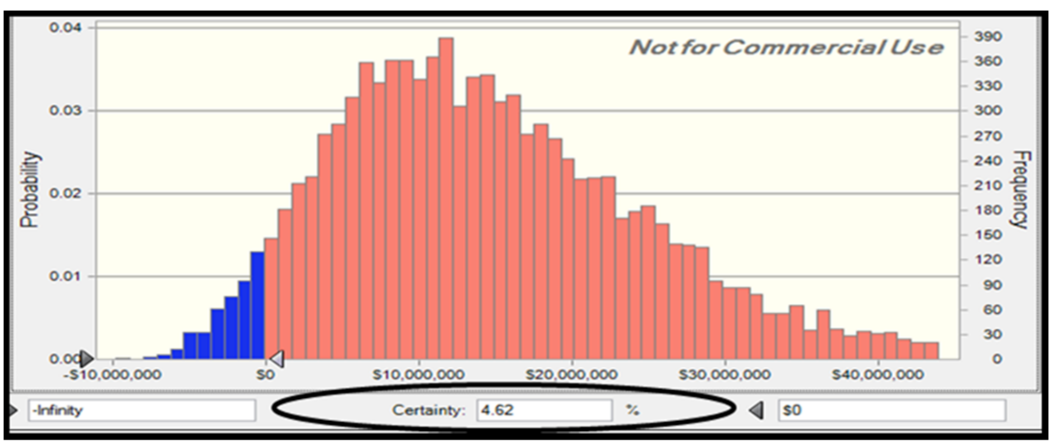
This subsection focuses on the cost and delivery performance results of the centralized system.

(1) Cost

According to the computations, the 95% confidence interval of the average cost savings from centralization is between $12,493,095 and $16,634,765. In other words, the method of computation—which is accurate 95% of the time—indicates that the average cost savings for the Navy will lie somewhere between $12,493,095 and $16,634,765 under a centralized system.

Overall, the model indicates that converting to a 2E centralized system would have a low risk of cost increase. After running 10,000 simulated years, the model determined that there is a 4.62% probability that a centralized system would cost more than the status quo system. That means the model estimates that 95.38% of the time (or 9,538 out of 10,000 times) it will cost less to operate a centralized system. Figure 6 depicts the output of the model and how the data is interpreted. The output in Figure 6 represents the net costs distribution of 10,000 simulated iterations when converting to a centralized system.

Figure 6. 2E Distribution of Centralized System Net Costs.

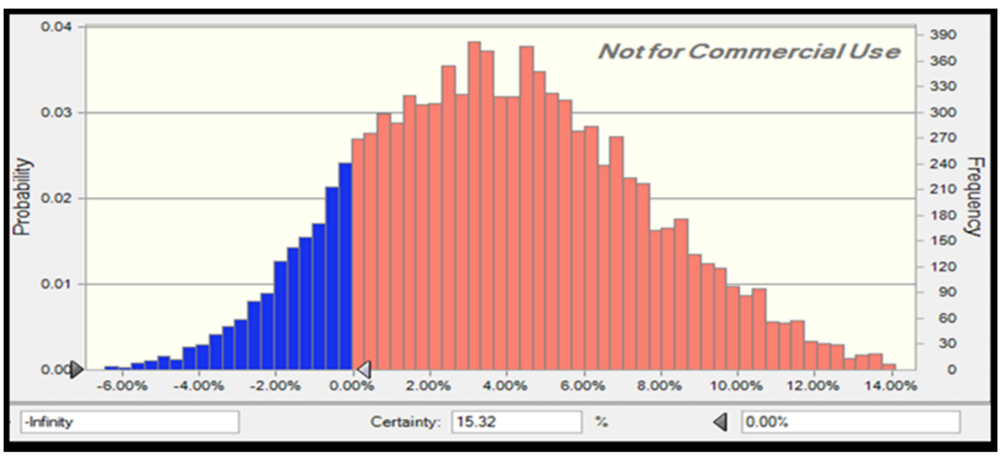


In Figure 6, the blue (the darker portion if viewed in black and white) portion of the distribution is the value at risk and represents the instances in the simulation where the centralized system costs more than the status quo; thus, the model's output reveals a negative net cost. A negative net cost was the result 4.62% of time. In Figures 7 through 13, the Certainty box at the bottom of the figure gives the relevant risk measure.

(2) Delivery Performance

The 95% confidence interval of the average delivery performance improvement lies between 3.77% and 3.91%. The model predicts that if the three NMCs were to convert 2E stock positioning to a centralized system, the 2E, as a whole, would, on average, improve delivery performance by a little less than 4%. As depicted by Figure 7, the model estimates that 84.68% of the time (or 8,468 out 10,000 times) a centralized system would result in better delivery performance than the status quo.

Figure 7. 2E Distribution of Centralized System Net RDD Success Rates.



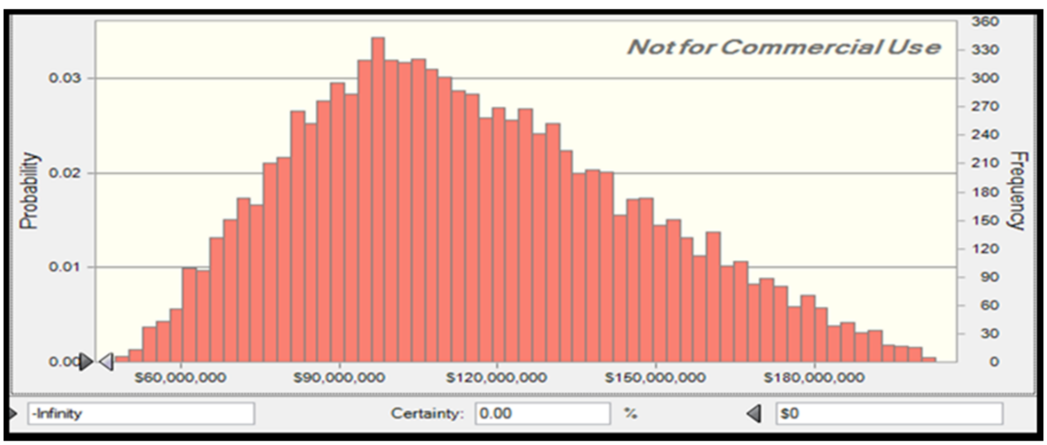
b. 2E Decentralized System Results

This subsection focuses on the cost and delivery performance results of the decentralized system. As mentioned earlier, for the decentralized system, it was assumed that each NMC would have a first-pass effectiveness of 98%. This means that each NMC can source 98% of its requisitions with its resident stock.

(1) Cost

The 95% confidence interval of average cost savings from decentralization for the Navy lies between $112,509,759 and $116,078,853 if it converted the three NMCs to a decentralized system for this COG. After running 10,000 simulated years in the model, the output reveals that the 2E decentralized system never costs the Navy more than the status quo. Thus, the model estimates that the decentralized system virtually always costs less. As seen in Figure 8, the model predicts virtually no risk of cost increase. As mentioned in both Chapter III and V, this is to some degree an artifact of our model, which is using Navy expenditures as a surrogate for costs. The model predicts that Navy expenditures are almost certain to decline under a decentralized business model.

Figure 8. 2E Distribution of Decentralized System Net Costs.

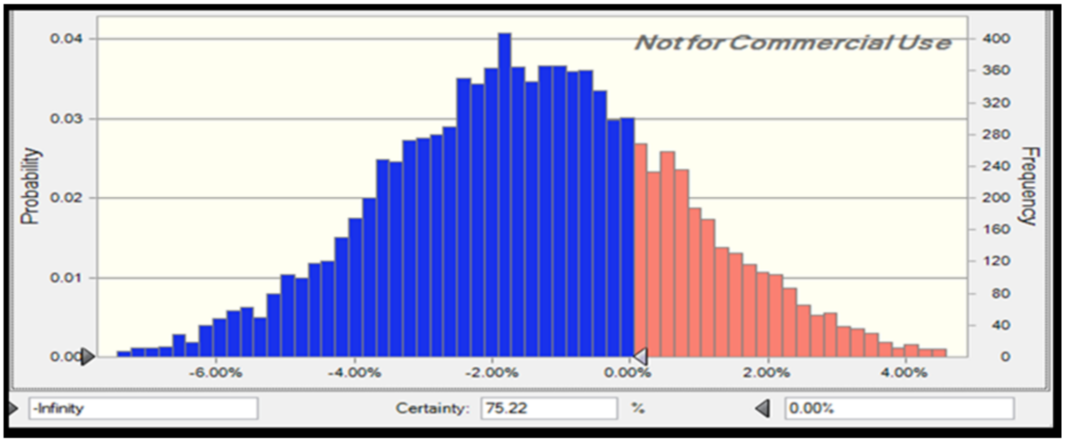


(2) Delivery Performance

The 95% confidence interval of the average delivery performance improvement from decentralization lies between –1.51% and –1.43%. This indicates that average delivery performance is expected to degrade by a little less than 1.5% if the stock positioning system is decentralized. As depicted by Figure 9, the model estimates that

24.78% of the time (or 2,478 out of 10,000 times) a decentralized system would result in better delivery performance than the status quo.

Figure 9. 2E Distribution of Decentralized System Net RDD Success Rates.



2. Cognizance 2T Results

For COG 2T, this section describes the results of the centralized system, followed by the results of the decentralized system.

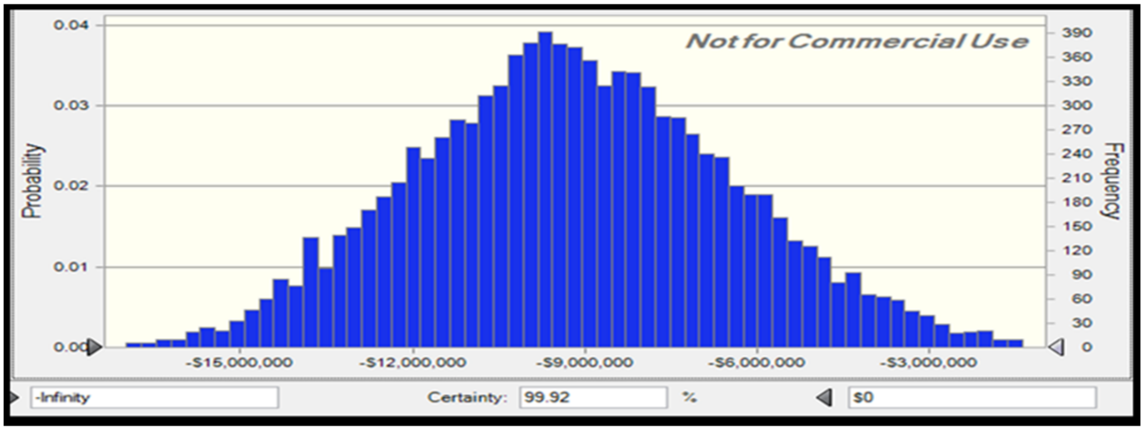
a. 2T Centralized System Results

This subsection focuses on the cost and delivery performance results of the centralized system.

(1) Cost

The 95% confidence interval of the average cost savings from centralization for the Navy lies between -$10,144,529 and -$8,190,723. The output of the model reveals that the 2T centralized system will have a 99.92% risk of cost increase from centralization, as depicted by Figure 10. This means that out of 10,000 simulations, almost all simulations indicated that the centralized system would be more expensive than the status quo.

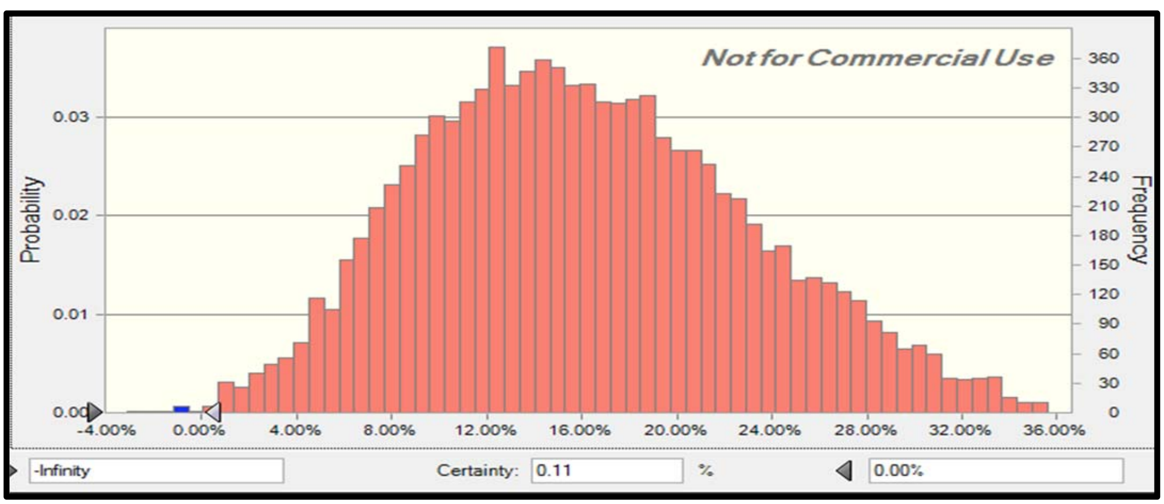
Figure 10. 2T Distribution of Centralized System Net Costs.



(2) Delivery Performance

The 95% confidence interval of the average delivery performance improvement lies between 16.10% and 16.36%. On average, the centralized system is expected to perform better than the status quo. As depicted by Figure 11, the model estimates that 99.89% of the time (or 9,989 out of 10,000 times) a centralized system would result in better delivery performance than the status quo.

Figure 11. 2T Distribution of Centralized System Net RDD Success Rates.



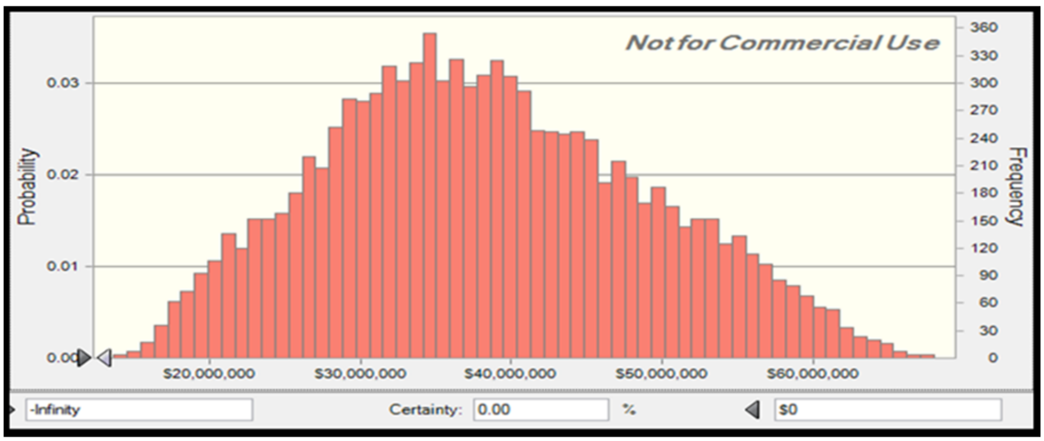
b. 2T Decentralized System Results

This subsection focuses on the cost and delivery performance results of the decentralized system. As mentioned earlier, for the decentralized system, it was assumed that each NMC would have a first-pass effectiveness of 98%. This means that each NMC can source 98% of its requisitions with its resident stock.

(1) Cost

The output of the model showed that a 2T decentralized system would cost less than the status quo system 100% of the time. The 95% confidence interval of average cost savings from decentralization for the Navy lies between $37,350,969 and $39,084,655. Figure 12 depicts the distribution of 2T Decentralized Net Costs.

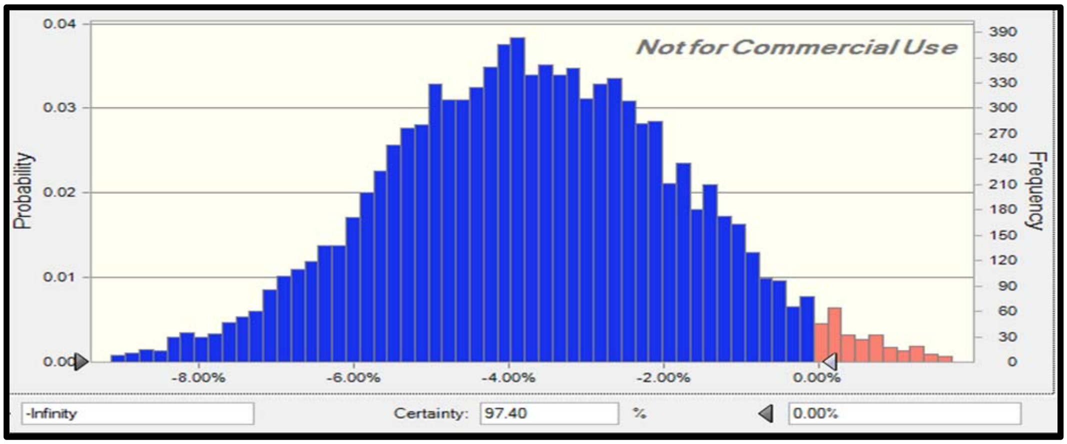
Figure 12. 2T Distribution of Decentralized System Net Costs.



(2) Delivery Performance

The 95% confidence interval of the average delivery performance improvement from decentralization lies between –3.77% and –3.69%. On average, the decentralized system is expected to perform worse than the status quo. As depicted by Figure 13, the model estimates that 2.6% of the time (or 260 out of 10,000 times) a centralized system would result in better delivery performance than the status quo.

Figure 13. 2T Distribution of Decentralized System Net RDD Success Rates.



The Navy's recorded history of relatively ineffective delivery performance (which may in part be an artifact of the way the data are captured, as explained in Chapter V) is reflected in the difference in RDD success between the status quo, and a decentralized system that would use the Navy system even more heavily.

C. SENSITIVITY ANALYSIS

1. Testing the Bounds of our Assumption

A constraint in the model is that the decentralized system would have a first-pass effectiveness rate of 98%. Thus, far, the results for COGs 2E and 2T have both shown that the decentralized system to be the least costly option by a wide margin. This, however, may be due to the generous assumption that the each NMC would fulfill customers' requests with their resident stock 98% of the time. This sensitivity analysis tests the limits of the first-pass effectiveness rate in the decentralized system. The objective is to see how low the first-pass rate could go for the three NMCs before the decentralized system no longer has the lowest average total cost, and how the delivery performance would be affected by the increase of site-to-site transfers.

2. Method

In order to find the threshold where the decentralized system no longer had the lowest average total cost, multiple simulations were run in which the first-pass effectiveness statistic was lowered by 10% increments for each NMC and run through 10,000 iterations until the point was reached where the decentralized system was no longer the low cost system. From there, first-pass effectiveness was increased marginally to find the nearest value lower than the best cost option. The first simulation for both 2E and 2T reduced first-pass effectiveness to 90% from the original 98% assumption.

The intent was to test the limits of the decentralized system to see how badly it can perform—with regard to stock positioning decisions—and still be the best cost option to reduce the Navy's operating costs. This analysis reveals how much room there is for error in the misallocation of initial inventory for each NMC.

As first-pass effectiveness is reduced, all other parameters are held constant, so that results are comparable. Because the data shows that the Navy has a better delivery performance with site-to-site transfers than delivery performance from on-site inventory, it was expected that the delivery performance will improve when a decentralized system relies more on site-to-site transfers with lower first-pass effectiveness.

3. Sensitivity Results

This section describes the results of the sensitivity analysis separately by COG, starting with COG 2E.

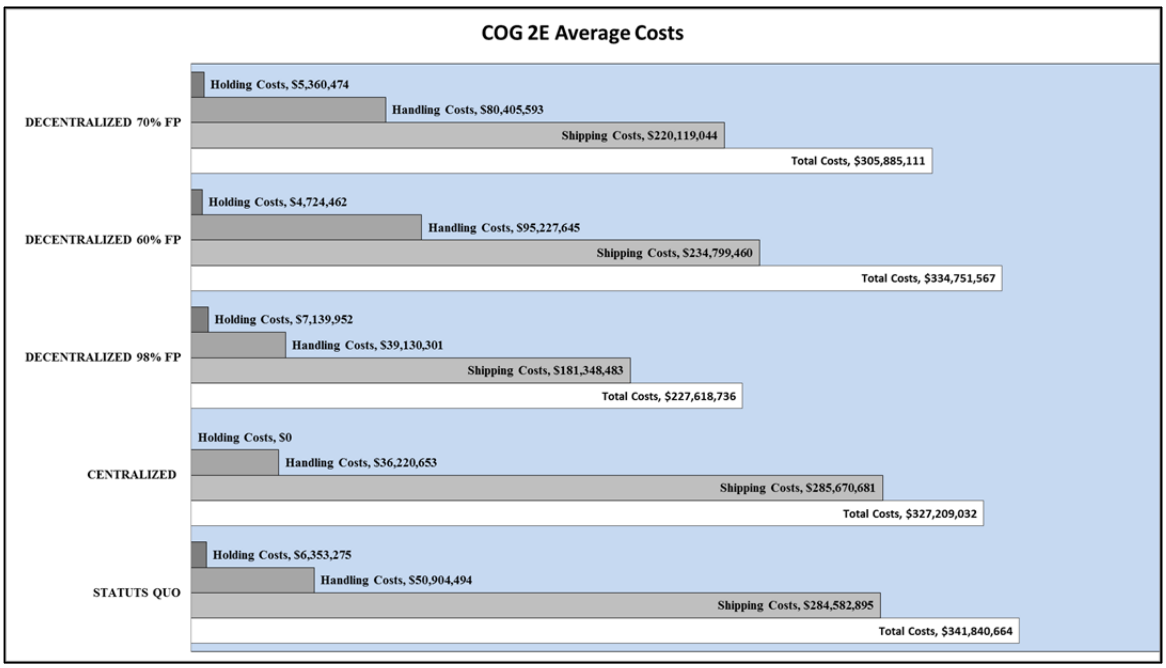
a. COG 2E Sensitivity Results

This subsection describes the results of cost and delivery performance for COG 2E. Cost results are described using average total costs for the simulations and delivery performance results are described using average net RDD success rate percentage.

(1) Cost Results

According to the additional simulations that were run, when each of the three NMCs of the 2E decentralized COG has a first-pass effectiveness of approximately 62%, it will no longer be the lowest cost option and the centralized system becomes the better option in terms of cost. Figure 14 visually depicts what happens to the total and individual costs when the decentralized system has to rely on more site-to-site transfers.

Figure 14. Cost Breakdowns for COG 2E Systems, Compared to the Decentralized System Under Varying First-Pass Effectiveness Rates.



A lower first-pass effectiveness rate means that more site-to-site transfers occur because the resident inventory cannot support local orders as effectively. Set-up costs are not displayed, but are factored into the total costs of the centralized system.

At the top of Figure 14, it can be seen that with each NMC fulfilling 70% of its orders on the first-pass (from resident inventory), the average total costs are still lower than the centralized and status quo systems. This would allow the Navy some leeway with COG 2E crossover challenges if it were to transition to a decentralized system. The model indicates that COG 2E can have over 30% of it orders sourced by site-to-site transfers and that the Navy would still save money. Looking at Table 6 in Section III.C.5, in the past seven years, no NMC has had first-pass effectiveness lower than 77%; thus, no NMC has had to rely on that many site-to-site transfers under the status quo system.

Due to holding cost assumptions explained in Section III.C.8.d, it is clear that holding costs decline in Figure 14, when the first-pass effectiveness rate declines. Shipping and handling costs, however, start to creep up with increased site-to-site transfers and the total cost exceeds the total cost of the centralized system at about 62% first-pass effectiveness. Once again, this reveals the notion that improperly positioning stockpiles away from its point-of-need, costs the Navy a lot of money.

(2) Delivery Performance Results

As expected, the model depicts that the average net RDD success rate will increase when more ammunition is supplied to the NMCs by site-to-site transfers. Table 15 shows that the average net RDD success rate starts to develop a net gain at around 65% for first-pass effectiveness. This solidifies the pattern that has been established in the data and the model.

Table 15. 2E Decentralized: Average Net RDD Success Rate Under Varying First-Pass Effectiveness Rates.

First-Pass Effectiveness	Tonnage Transferred	Average Net RDD Success Rate
90%	26,071	–1.07%
80%	52,031	–0.64%
70%	78,150	–0.22%
60%	104,465	0.18%
50%	130,542	0.66%
40%	156,272	1.06%

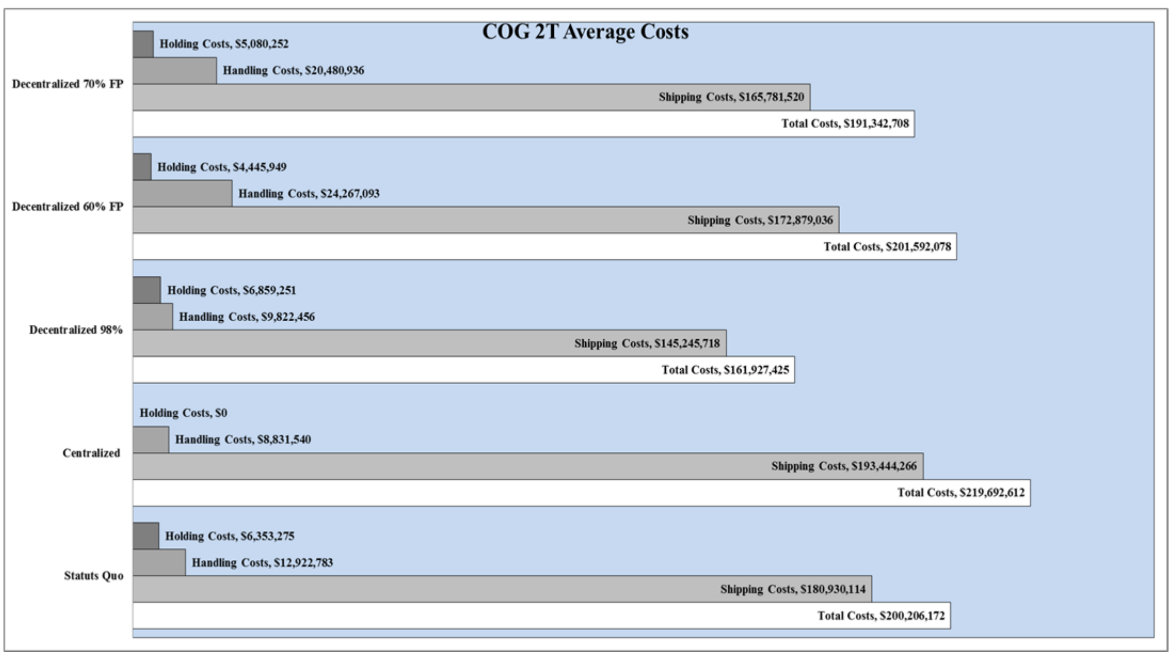
b. COG 2T Sensitivity Results

This subsection describes the results of cost and delivery performance for COG 2T. Cost results are described using average total costs for the simulations and delivery performance results are described using average net RDD success rate percentage.

(1) Cost Results

As seen in Figure 15, once the NMCs of the 2T decentralized system start to reach about 60% first-pass effectiveness, decentralization is no longer the low cost alternative to the status quo system. The status quo system starts to become more cost effective by over $1M at the 60% first-pass level. Similar to the 2E decentralized system, the 2T decentralized system can operate with 30% of its orders being provided by site-to-site transfers and still be less costly than the other alternatives. Again, this may provide the Navy with hefty room for error if the decision is made to convert to a decentralized system.

Figure 15. Cost Breakdowns for COG 2T Stock-Positioning Systems, Compared to the Decentralized System Under Varying First-Pass Effectiveness Rates.



(2) Delivery Performance Results

Similar to the 2E performance sensitivity analysis, Table 16 shows that the average net RDD success rate goes up as first-pass effectiveness declines. The 2T average net RDD success rate, however, becomes a positive percentage much sooner than 2E. Positive net RDD performance occurs at about a 72% first-pass effectiveness rate. This shows that each COG has its own individual characteristics and that one rule, for one COG, might not apply to another because all the key variables that affect cost and performance are different.

Table 16. 2T Decentralized: Average Net RDD Success Rate Under Varying First-Pass Effectiveness Rates.

First-Pass Effectiveness	Tonnage Transferred	Average Net RDD Success Rate
90%	6,133	–1.23%
80%	12,288	–1.02%
70%	18,399	0.41%
60%	36,825	1.87%
50%	30,706	3.37%
40%	24,499	4.91%

V. CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER RESEARCH

A. OVERVIEW

This chapter summarizes the results of the model, underlying limitations, and assumptions made. Following that, this chapter discusses the recommendations for stock positioning based off of the output of the model. Finally, this project concludes with recommendations for future analysis that will hopefully strengthen this area of research.

B. SUMMARY OF RESULTS

As seen in Table 17, the decentralized system would have a higher average cost savings and little-to-no risk of cost increase for both COGs; however, it appears that decentralizing the ammunition stockpiles would have a lower average delivery performance improvement with a high risk of delivery performance degradation. Centralizing, on the other hand, had conflicting results, as centralizing COG 2E would have a lower average cost savings and high risk of cost increase, as well as a higher average delivery performance improvement with a low risk of delivery performance degradation.

Table 17. Summary of Results for COGs 2E and 2T.

COG	System	Cost Risk	95% Confidence Interval: Average Cost Savings	Performance Risk	95% Confidence Interval: Average Delivery Performance Improvement
2E	Centralized	4.62%	\$12,493,095 to \$16,634,765	15.32%	3.77% to 3.91%
2E	Decentralized	0%	\$112,509,759 to \$116,078,853	75.22%	–1.51% to –1.43%
2T	Centralized	100%	-\$10,144,529 to -\$8,190,723	0.11%	16.10% to 16.36%
2T	Decentralized	0%	\$37,350,969 to \$39,084,655	97.40%	–3.77% to –3.69%

Summary of net costs and net delivery performance risk when each system is compared to the status quo within its perspective COGs.

1. Analysis of Cost Results

Looking at the stock positioning system strictly regarding costs, the optimal system to use is the one that minimizes holding, handling, shipping, and set-up costs. Any attempt to minimize one type of cost, however, seems to have an inverse effect on another cost. Ultimately, this balancing act of the aforementioned costs in the ammunition supply chain is what is analyzed. In the model, the different systems represent opportunities to minimize one type of cost at the expense of another cost in the following manner:

- **Centralized system:** The Navy technically eliminates holding costs (because the costs move to another budget), but then incurs set-up costs and increased shipping costs from material returns. With the centralized system, handling costs are greatly reduced by the elimination of site-to-site transfers.
- **Decentralized system:** An attempt to decrease handling costs by increasing first-pass effectiveness and, thus, decreasing site-to-site transfers. This method incurs greater holding costs, as more inventory is held at the NMCs.
- **Status quo:** A possible middle-ground attempt to balance control of inventory, readiness, and costs.

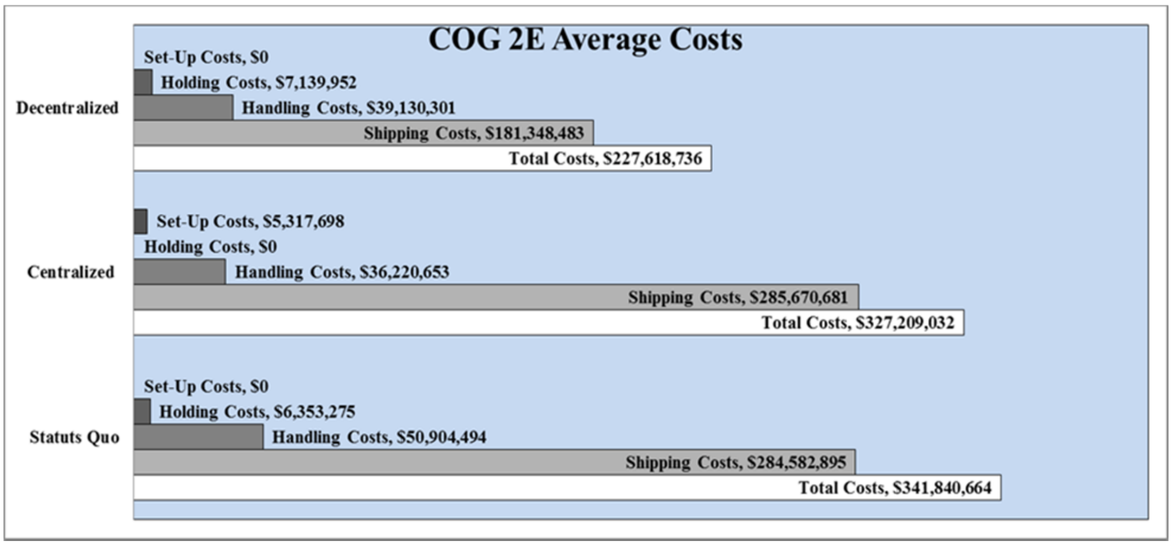
Subsections (1) and (2) break down the different costs for each system to reveal the factors that influenced net costs.

a. Analysis of Cognizance 2E Costs

This subsection analyzes the handling, set-up, shipping, and holding costs for each stock positioning system of COG 2E using the mean/average output values of each cost category, which were a result of the 10,000 simulations conducted by the model. Average values are used to find relative values for each cost to conduct comparisons for each cost category.

As seen in Figure 16 and in earlier results, 2E status quo had the highest average total costs among all three stock positioning systems. This is because it had the highest handling costs and almost the highest shipping costs, which is explained by the fact that under the status quo system, site-to-site transfers happen more often than with any other stock positioning systems. The decentralized system is the only other system that depends on site-to-site transfers, but they occur less frequently than with the status quo system. In the 2E status quo system, the average amount of tons transported in site-to-site transfers in one year was 26,060 tons. The decentralized system transferred an average of 5,227 tons from site-to-site and, thus, the decentralized system had significantly lower shipping and handling costs than the status quo system.

Figure 16. Cost Breakdowns for COG 2E Stock-Positioning Systems Using Average Cost.



In any system, shipping and handling costs rise significantly when specific ammunition is not positioned where it is needed. When ammunition takes an indirect route to its final destination, it is a waste of resources; in other words, site-to-site transfers are a waste of resources. The centralized system, as displayed in Figure 16, has high shipping and handling costs due to the returns that were factored into the model. The model factors in all the shipments and returns back to the Army. On average, the 2E centralized system processed 152,577 tons of returns back to the Army because the NMCs were not allowed to hold any inventory. So, again, extra shipping and handling costs are being incurred to ship ammunition back to the Army. This seems like a total waste of resources, but it should be highlighted that the 2E centralized system still costs less, with its higher tonnage of returns than the status quo system and its site-to-site transfers.

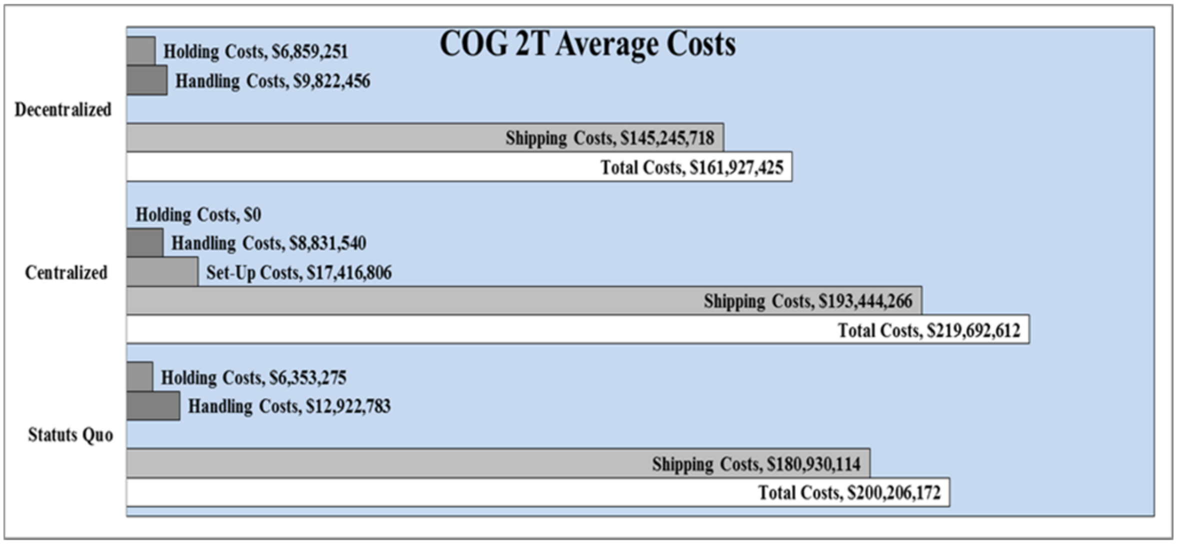
Site-to-site transfers seem more costly to a 2E supply chain than returns in a centralized system. One explanation might be because handling costs are lower with returns. The Army does not charge the Navy handling costs for order fulfillments and returns. Site-to-site transfers incur additional handling costs to the Navy at every stop. So theoretically, a point-to-point return from an NMC to the Army can travel the exact same distance as a site-to-site transfer, but because a site-to-site transfer in total has at least one connecting destination, it incurs at least two installation-handling fees, whereas a return only incurs one Navy installation handling fee for the bundling and shipping of the return. With 2E, the shipping costs are, on average, almost the same between the centralized and status quo, but the average centralized handling costs are almost $15M lower and, thus, the 2E centralized system was cheaper than the 2E status quo system.

In the end, the decentralized system is the most cost-effective system for COG 2E. Figure 16 shows that even though it had, on average, $786,667 in higher holding costs than the status quo, it had, on average, $115,008,605 less in combined handling and shipping costs. When using a decentralized system, there seems to be a disproportionate yet, favorable, trade-off between additional holding costs and the reduction of handling and shipping costs.

b. Analysis of Cognizance 2T Costs

In the 2T supply chain (see Figure 17), the centralized system is much more costly than the other systems and the decentralized system is, again, the cheapest method, on average.

Figure 17. Cost Breakdowns for COG 2T Stock-Positioning Systems Using Average Cost.



The main difference between the 2E supply chain and the 2T supply chain is that the average set-up costs and the average shipping costs combine to make the centralized system more costly than the status quo system. In the 2T centralized system, the average shipping costs are a little higher in comparison to the 2T status quo shipping costs, but are still within $13M of each other. Since 2T has different demand patterns, shipping rates, and rates of return compared to COG 2E, the cost relationship between stock positioning systems will vary. This explains why the centralized system is cheaper than the status quo for 2E.

The model reveals that decentralizing the stockpiles has the lowest risk of cost increase and the most possible cost benefit in COG 2E despite it having the highest holding costs. The decentralized system again has the lowest average shipping costs because it has to rely on site-to-site transfers very few times and it does not return offloads back to the Army. In the 2T supply chain, the decentralized system site-to-site transferred an average of 1,228 tons, the status quo system transferred an average of 5,089 tons and the centralized system was required to return, on average, 21,894 tons of offloaded ammunition back to the Army.

2. Analysis of Delivery Performance Results

To understand why the model always finds the centralized system to have low risk of delivery performance degradation and the decentralized systems to have a high risk of delivery performance degradation, one only needs to look at the historical RDD success rates in Table 9 of Section III.C.7. Almost all the RDD success rates for each NMC reveal that the Army (the centralized source) has the highest average RDD success rate. The notion that the Navy's delivery performance decreases as first-pass effectiveness increases is counterintuitive and indicates that the data may be unreliable.

This project did not involve investigating why resident-sourced delivery performance is worse. It can be assumed that the LMS personnel are more focused on the high-visibility, intricate orders that have to be sourced by the Army or through site-to-site transfers. Thus, the personnel are more diligent in seeing those complicated, site-to-site transfers through to the last step—which occurs when the customer administratively receipts for the ammunition on OIS-R—to ensure that all the moving pieces came together. It is possible that when LMS personnel know a requisition is going to be fulfilled by resident stock of the NMC, it quickly falls off their radar and, consequently, they are not as forceful in ensuring that the customer receipts for the ammunition on or before the RDD.

Possibly, a decentralized system would have the opposite effect of what the model predicts; which is a high risk of delivery performance degradation. As mentioned before, the RDD success rates were reflective of the data provided by NAVSUP GLS AMMO and were not manipulated to be in favor of any system based on the assumption that stock positioned closer to demand would result in more favorable delivery performance. Section C discusses some of the limitations of the data and why it may be possible that a decentralized system's delivery performance would not be as low as the model estimates.

C. LIMITATIONS

This section covers some of the issues with the data provided, and with model assumptions necessary because of data availability or time restrictions, which limit the generalization and implications of the results.

1. Time-Stamped Data

The NMC personnel can choose to process a specific order when they deem it necessary, based on the priority of the order, the RDD, and the current requirements of other orders. Additionally, the time that a material receipt confirmation is dated in OIS may not show when the actual ammunition was receipted; it only indicates when the administrative process of inputting the material receipt confirmation took place.

The inherent weakness in the data is the use of time-stamped transactional data. It is a prediction that not all requisitions deemed "late" were actually late. There is a possibility that many requisitions were marked not meeting the RDD because it was stamped (receipted-for) long after the order was received, post-RDD. Following up on this intuition, which would have required auditing a significant sample of late orders and confirming with personnel if, in fact, the samples were late, went beyond the scope and time frame of this project.

As mentioned earlier, there may not be as much urgency placed on customers to quickly indicate in the supply system that they received their requisition before the RDD. This can be especially true if there is a lot of ammunition to count and verify, or if an order was received right before a period of liberty. NAVSUP's data makes it very difficult to use in any detailed analysis, unless every organization in the supply chain is administratively inputting time stamps closely to when the corresponding actions occurred. It is somewhat futile to measure the success of NAVSUP GLS AMMO by the delivery performance standard if the data used to dictate success or failure is inaccurate by nature.

2. Transportation Capacity

Within the model, some sweeping assumptions were made about the capacity of transportation assets for both the Army and the Navy. This project did not capture the effects that increased shipments would have on the transportation assets of the Army and Navy, and, therefore, it did not factor in how lead times would increase because shipping capacity would be strained. There was not enough information about the capacities of the transportation assets and it went beyond the scope of this project.

It may be worth mentioning that if a decentralized system is to be implemented, the Navy should be prepared to increase the capacity of shipping assets, if necessary. Likewise, if a centralized system were to be implemented, the Navy would need to factor in the increased transportation costs for returns and expect the Army to pass on some of their transportation costs.

3. Shipment Sizes

In this project, it was assumed that the number of shipments would be independent of the size of the orders. In a supply chain system, it may be a natural occurrence for the sizes of orders to increase if the total amount of shipments for the year decreased. This project ignored this phenomenon and treated order sizes and tonnage of shipments as independent variables. This was done to replicate the order sizes that individual units demand and to replicate an individual unit's lack of concern for economies-of-scale when ordering their own requirements.

4. Shipment Times with Regard to Tonnage

Another assumption that was made in this project was that the tonnage of orders did not have any effect on their response time or the probability that they would or would not meet their RDD. Unfortunately, this type of analysis was well beyond the scope and time bounds that were available, but there may be an interest in seeing if there is a correlation between tonnage and logistics response time.

D. RECOMMENDATIONS BASED ON THE OUTPUT OF THE MODEL

It is recommended that the Navy explore decentralization of its ammunition stockpiles on an incremental basis to observe the effects with the different COGs. The output of the model indicates that the shipping cost is the lowest for a decentralized system. This could imply that the decentralized system may provide cost savings for those COGs that experience high shipping costs in the status quo.

Since every COG has unique demand, shipping, and cost patterns, it is recommended that every COG be given individual consideration before committing to decentralization. The different characteristics of each COG will prevent a one-size-fits-all model from determining decentralization feasibility for all; therefore, it is recommended that a similar methodology to the one used in this project be utilized.

From a cost risk standpoint, it appears that decentralization has the lowest risk of cost increase for both COGs. Since the sensitivity analysis demonstrated that significant reliance on site-to-site transfers with a decrease in first-pass effectiveness is still cost effective, there would be less pressure to initially forecast the right amounts of inventory to give to each NMC.

Because of the limitations of time-stamped data that were discussed previously, it is recommended that the Navy analyze its current business process associated with receipt transactions to determine if a kaizen event can be coordinated to improve the accuracy of this process. Without data that is reflective of actual events, it is difficult to measure actual delivery performance and it may be impractical to predict the behavior of a system with inaccurate data.

E. RECOMMENDATIONS FOR FUTURE RESEARCH

It is recommended that the following topics be explored further:

- The effects of decentralization and centralization on other COGs using additional years of data
- Refined analysis into the effects of order size and RDD success

- Refined analysis into what the actual delivery performance is of the Navy under current administrative behaviors
- Analysis of transportation capacities that would be required for decentralization
- The effects of using real-time tracking technology in the Navy ammunition supply chain

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